ATLAS AT THE START OF RUN II

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Duke University

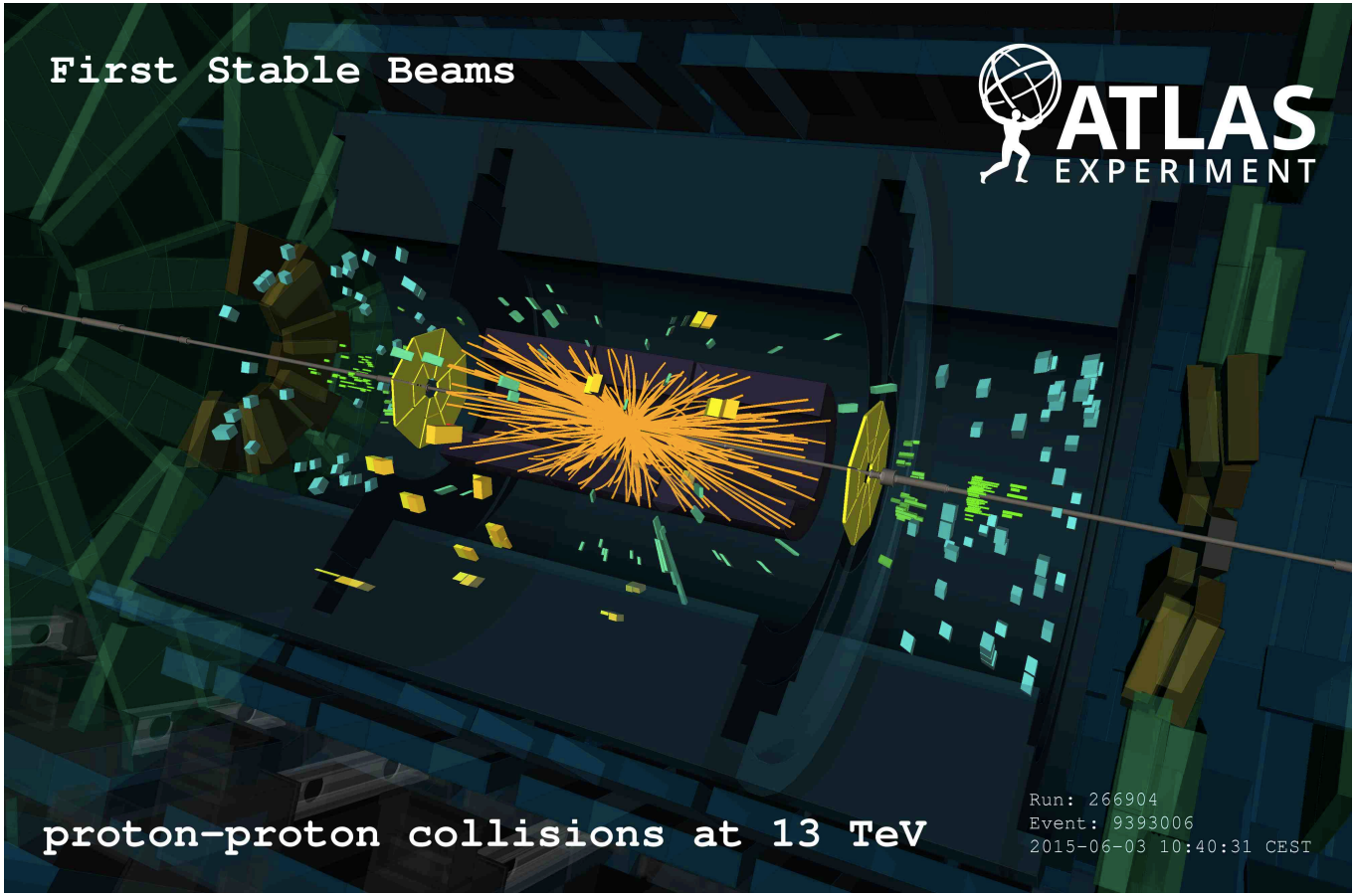
Brookhaven Forum 2015:
Great Expectations, A New Chapter

ATLAS EXPERIMENT

what to expect...

- The ATLAS experiment could witness ~10^{16} proton collisions at 13(+) TeV by the end of 2018

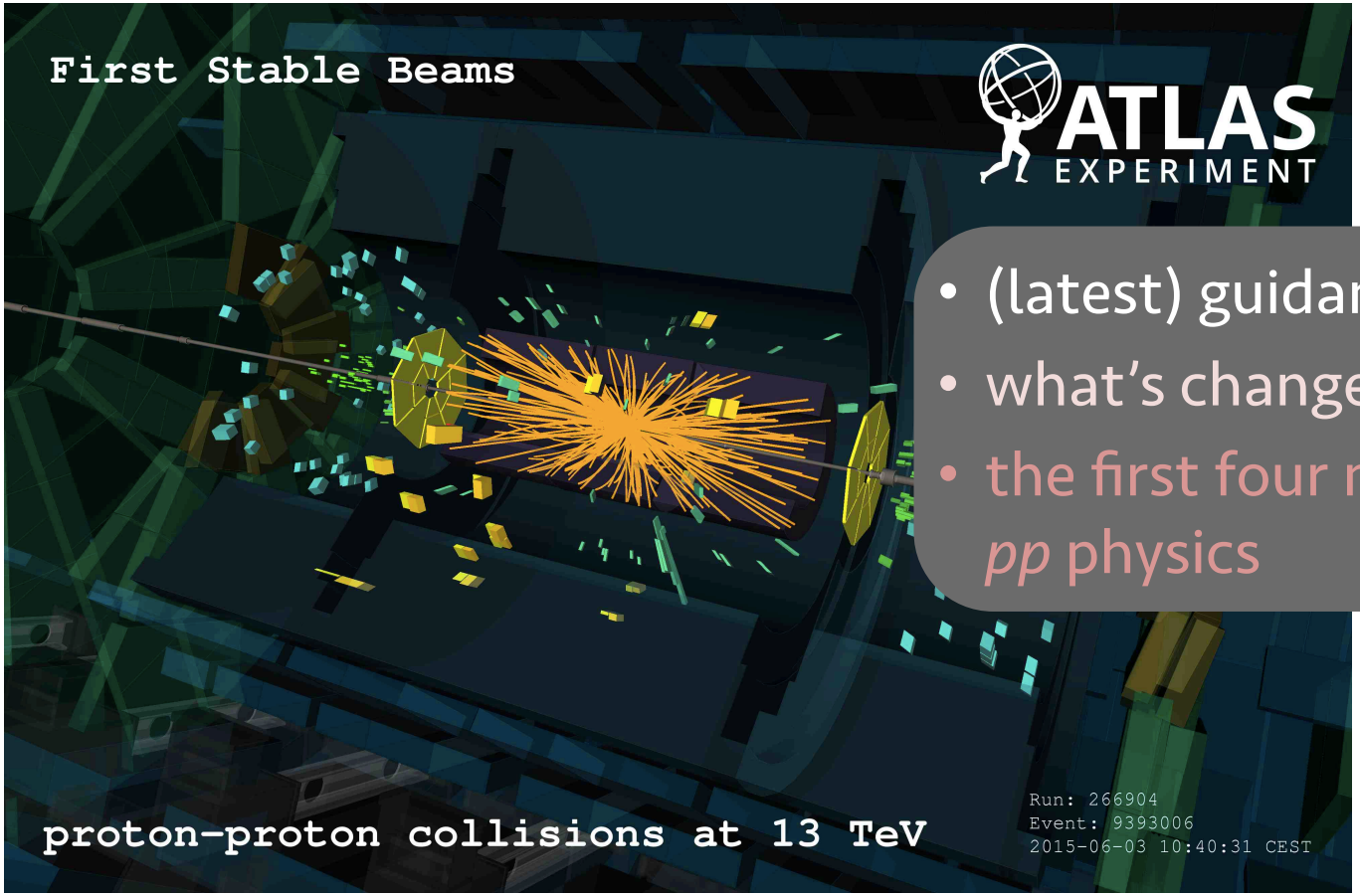
What can we expect from ATLAS in Run II?



what to expect…

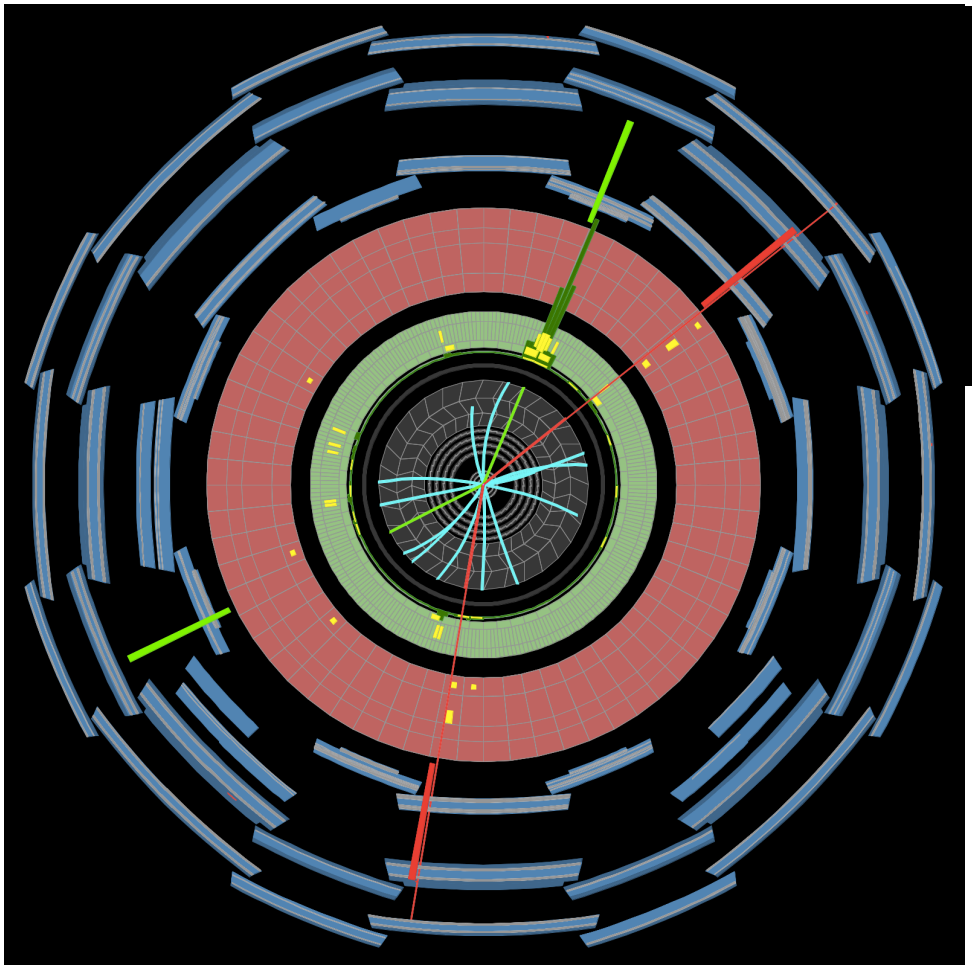
- The ATLAS experiment could witness ~10^{16} proton collisions at 13(+) TeV by the end of 2018

What can we expect from ATLAS in Run II?

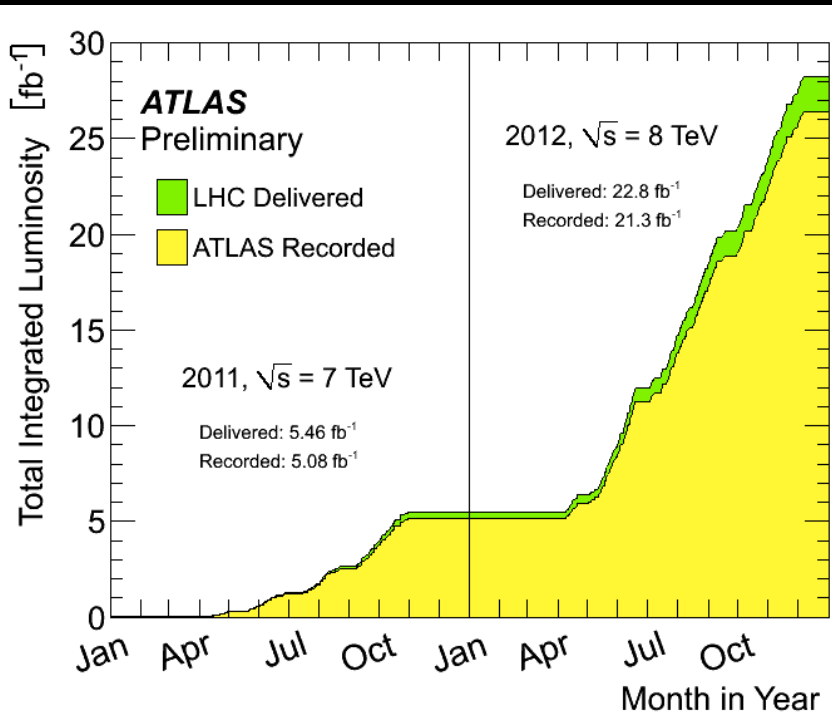


- (latest) guidance from Run 1
- what's changed?
- the first four months of 13 TeV *pp* physics

guidance from Run 1

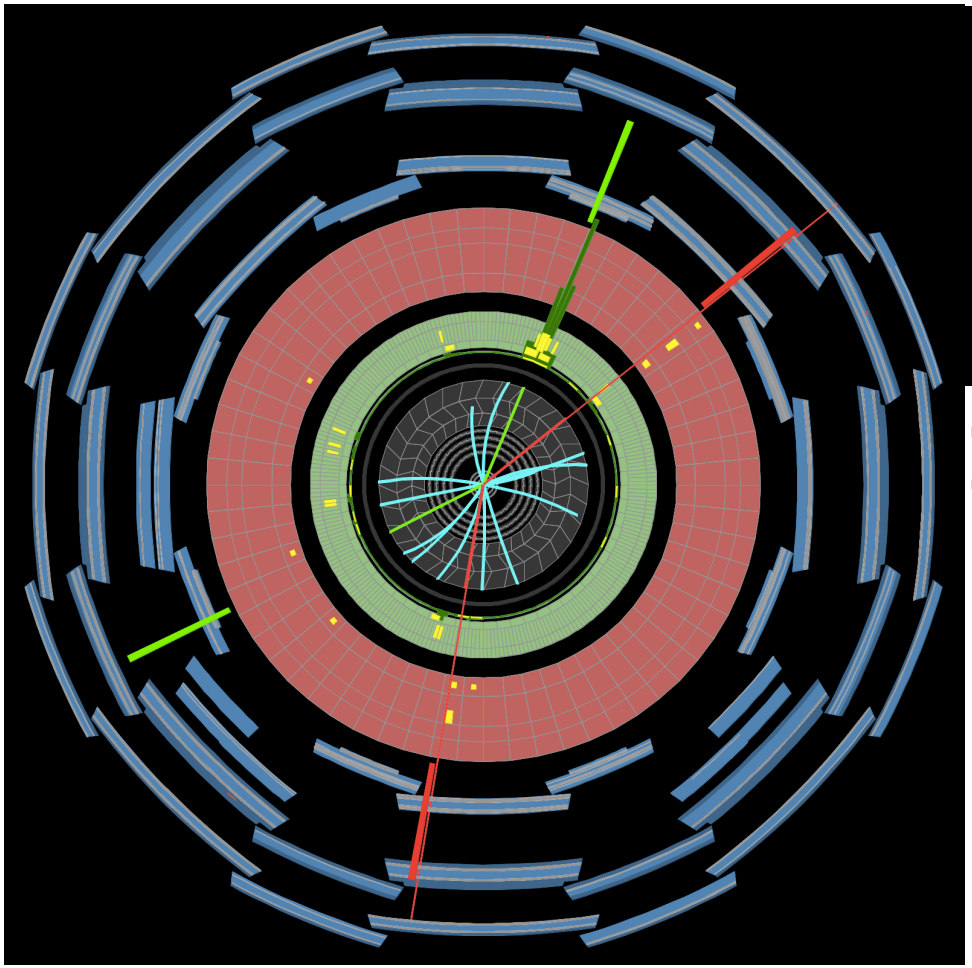


Status: Oct 2012
muon subsystems: >96%
Tile calorimeter: 98.3%
Central EM calorimeter: 99.9%
Tracker: 97% (TRT) 99%(Si) 95% (Pixel)



excellent LHC and detector performance

guidance from Run 1



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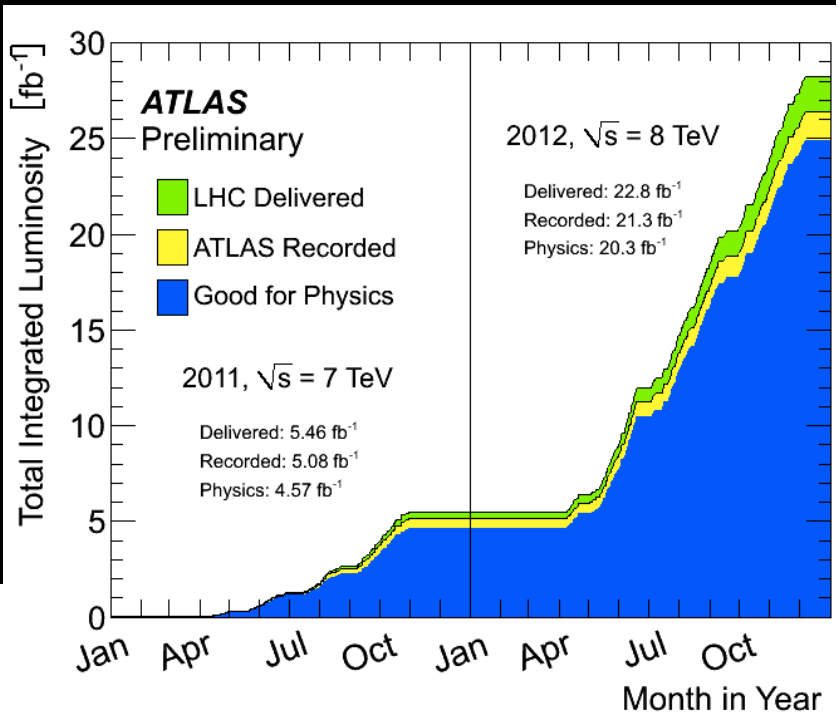

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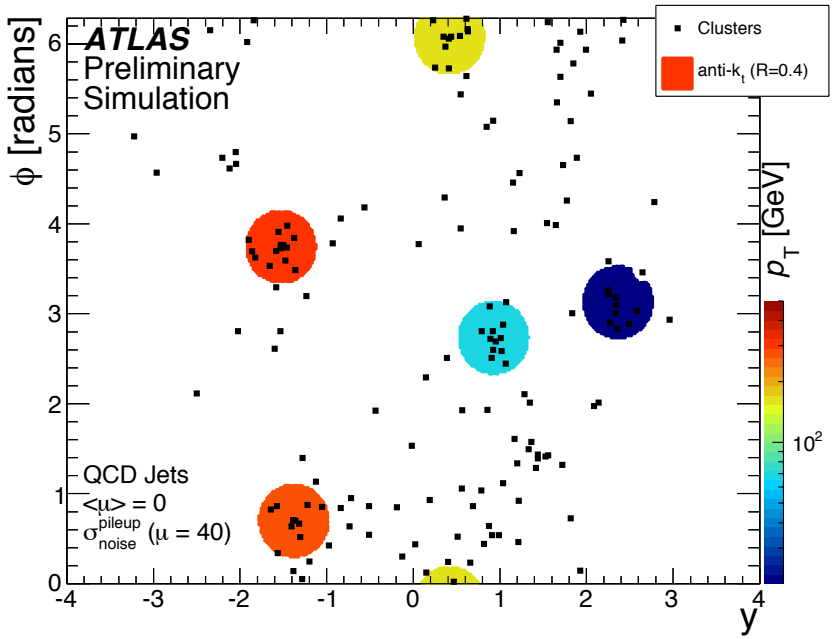
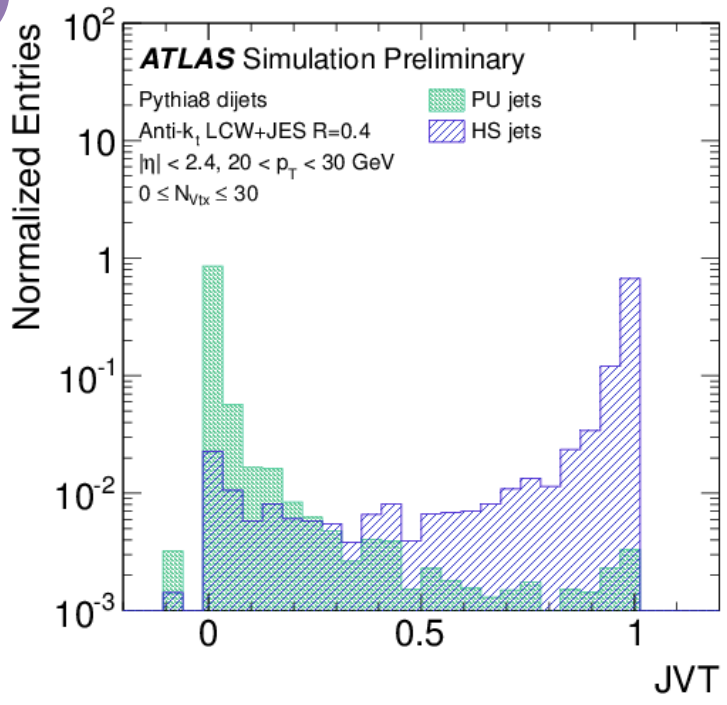
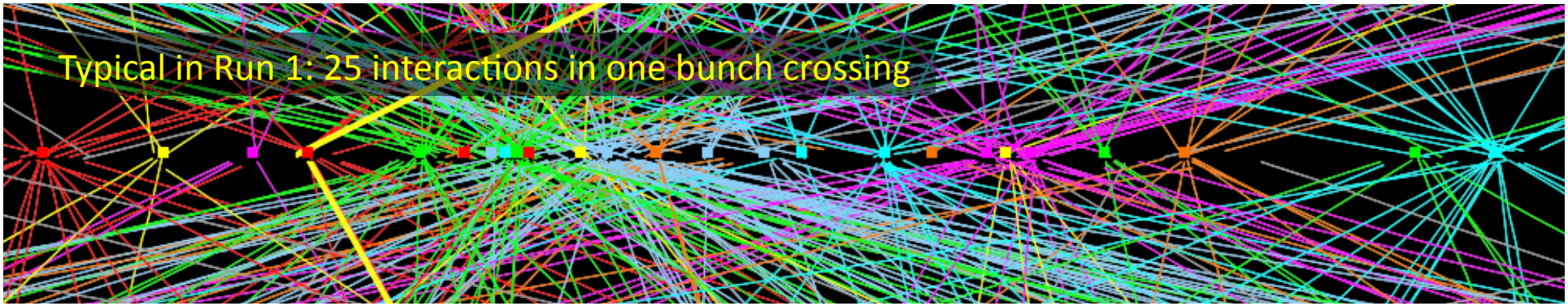
guidance from Run 1

cost of high luminosity (pileup) … can be managed







guidance from Run 1

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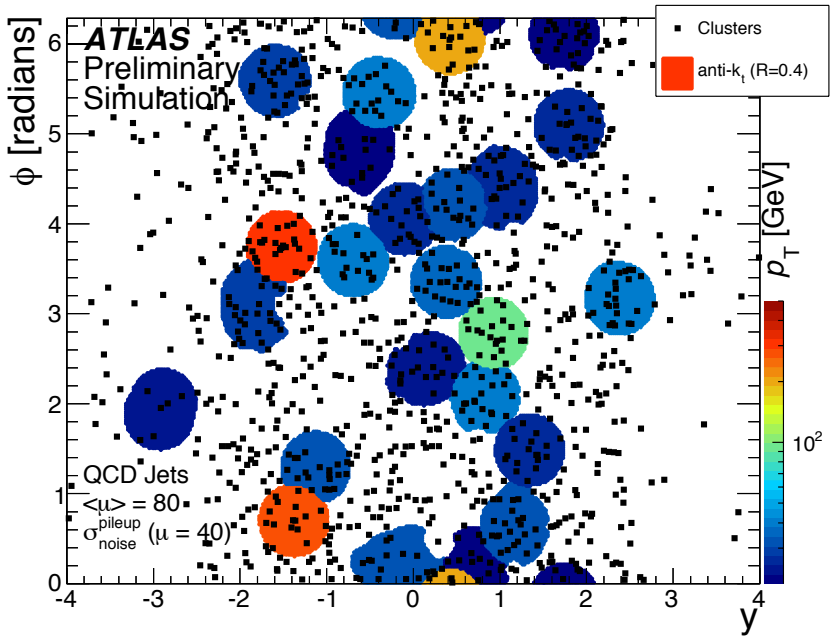
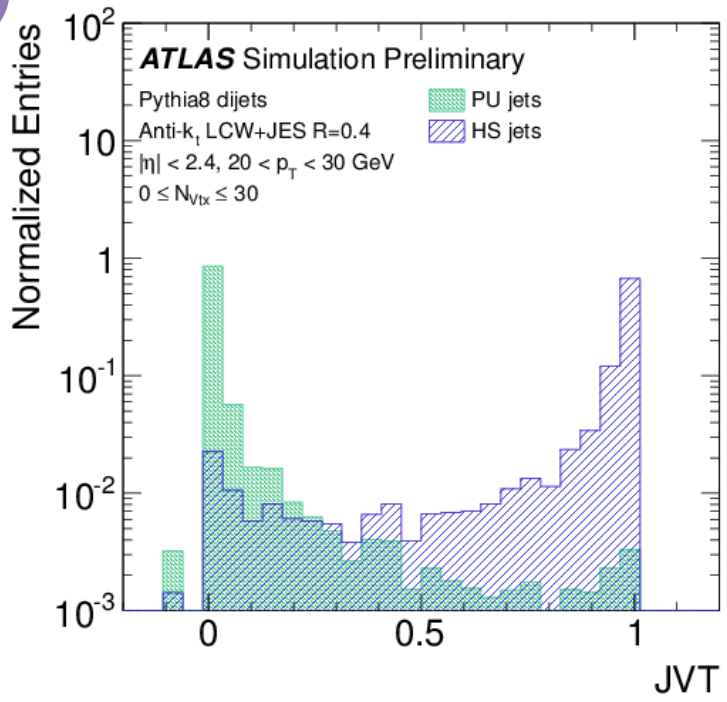
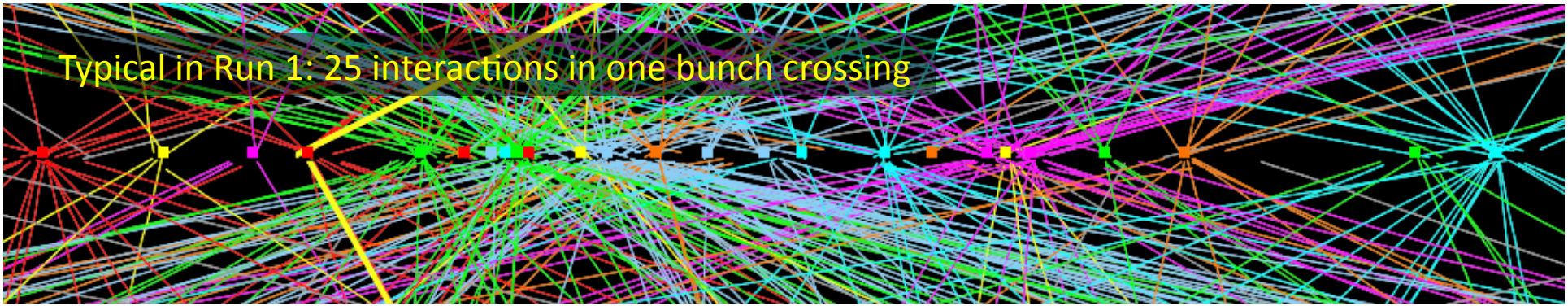


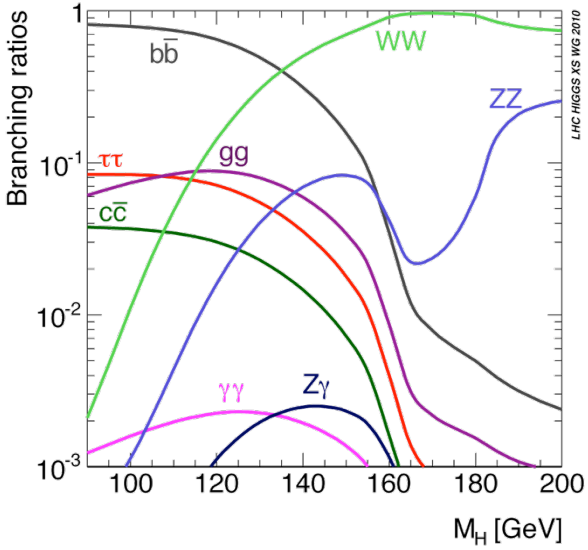


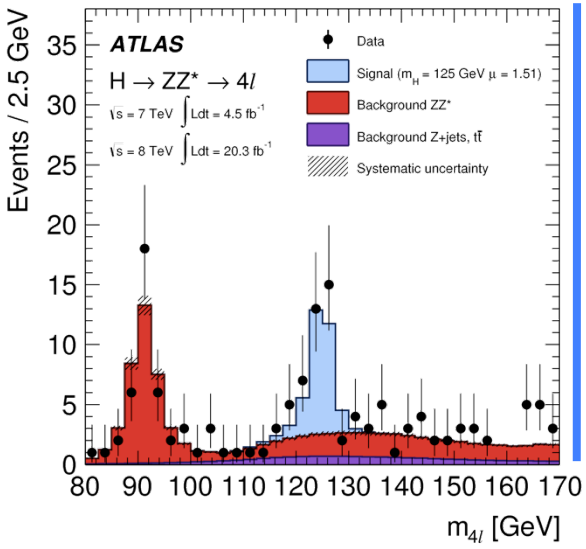


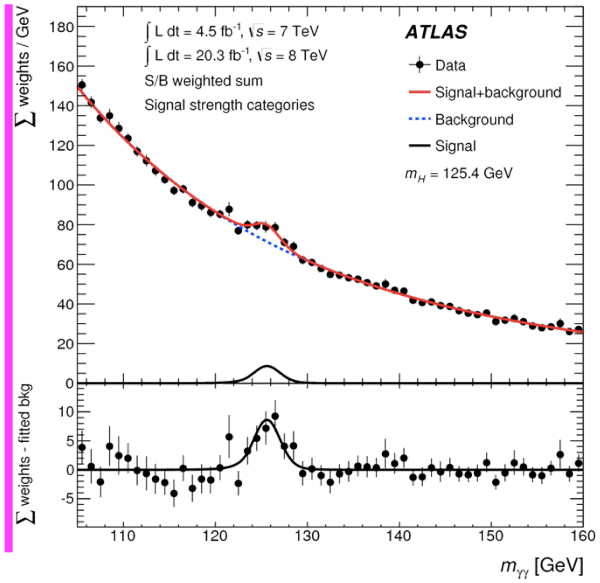
guidance from Run 1

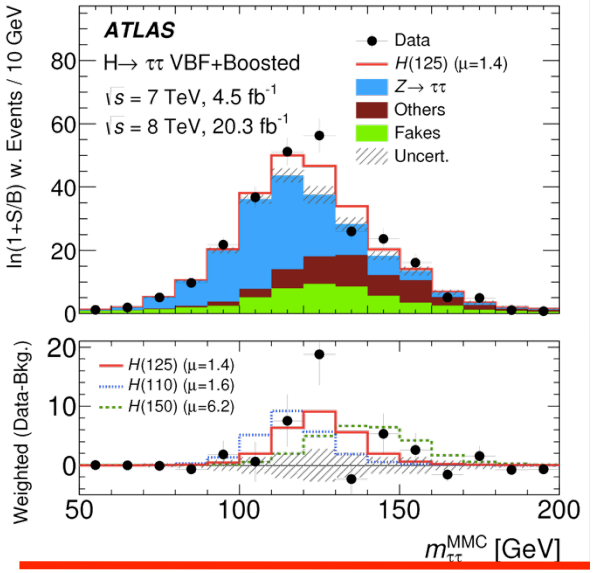
Higgs boson events come in flavors

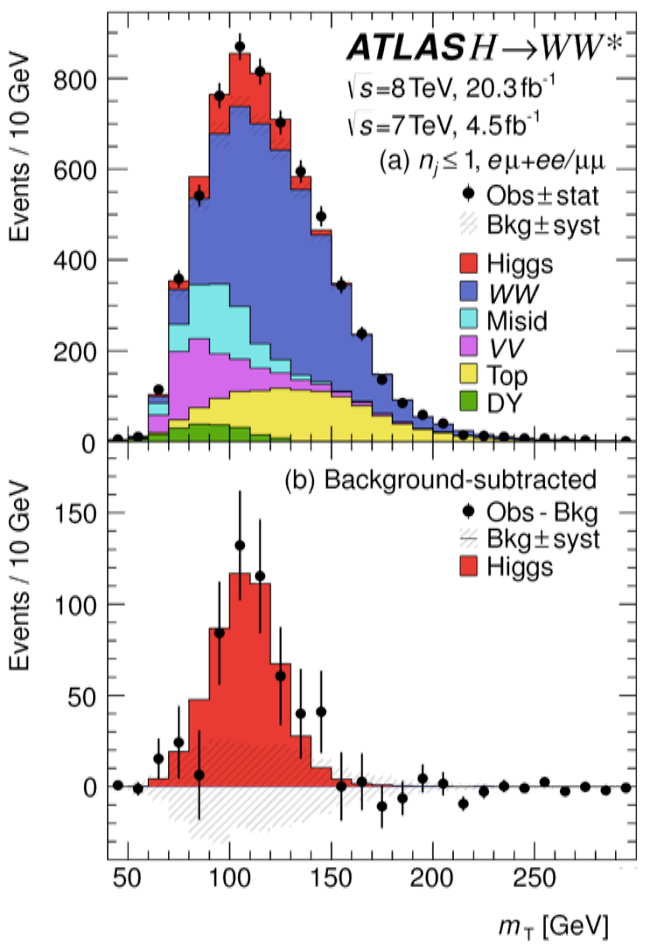
PRD 91 012006 (2015)
PRD 92 012006 (2015)
JHEP 1504 (2015) 117
PRD 90 112015 (2014)









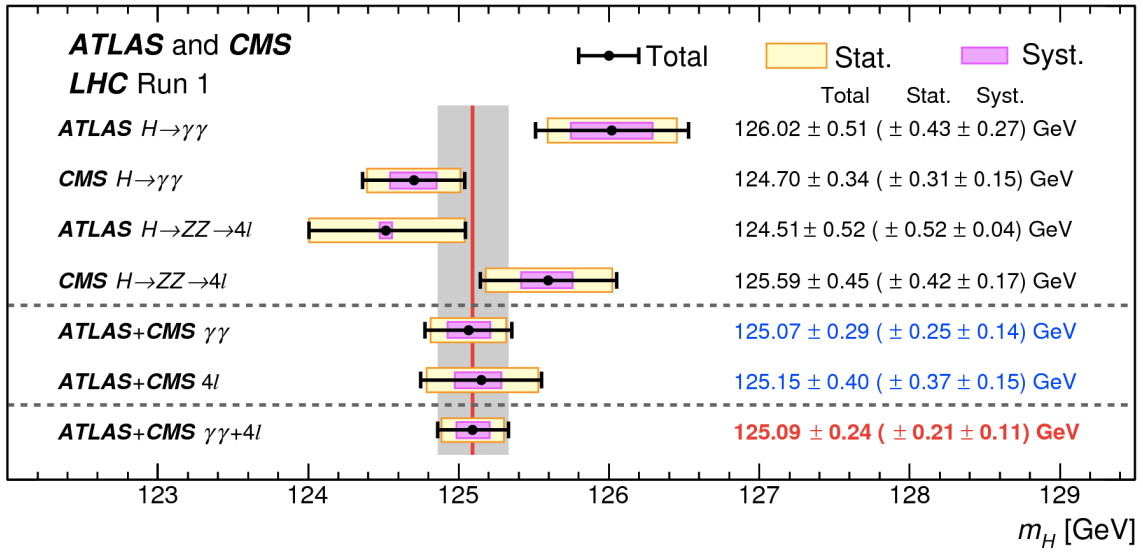


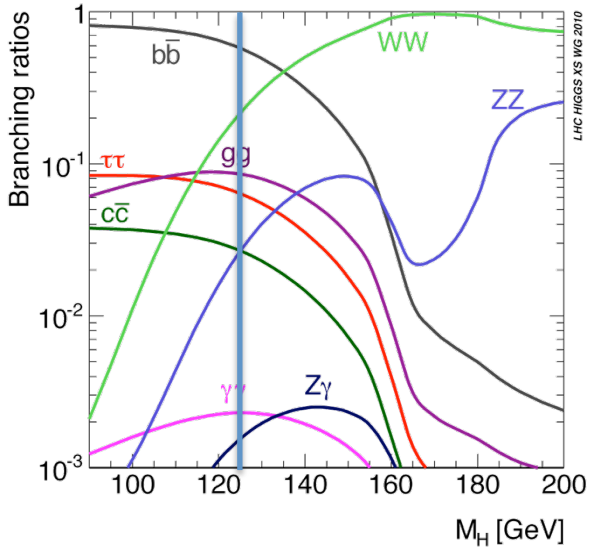
many specialized "laboratories" for studying properties

PRL 114 191803(2015)

guidance from Run 1

SM completely constrained





m_H= 125.09 ± 0.24 GeV*

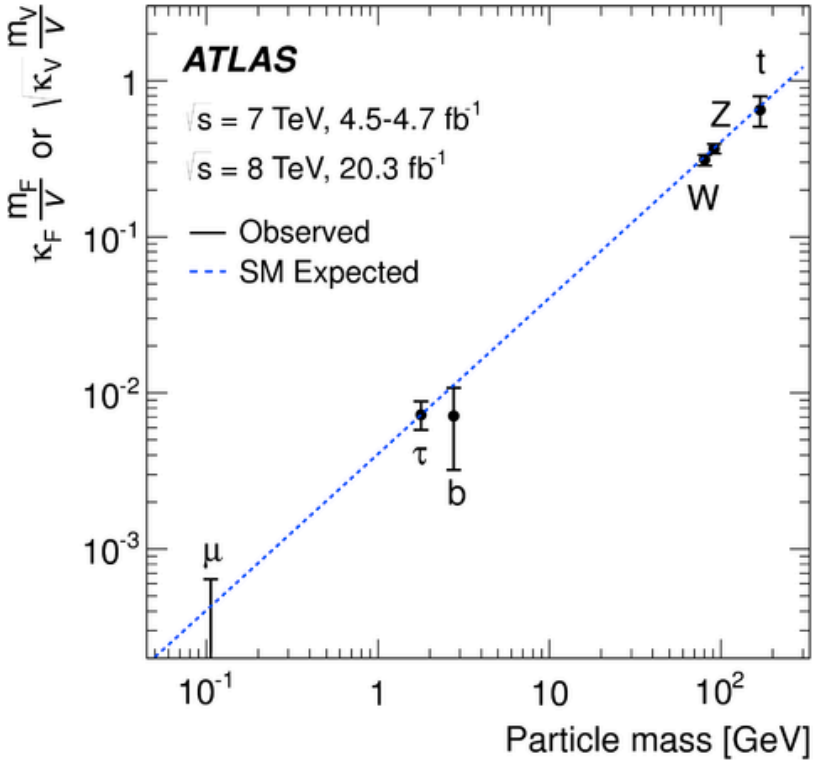
- improvement gives more precise coupling predictions for bosons
- still statistics limited!
  - dominant ATLAS systematic uncertainties from calibrations of electromagnetic and muon energy scales (from Z, J/ψ)

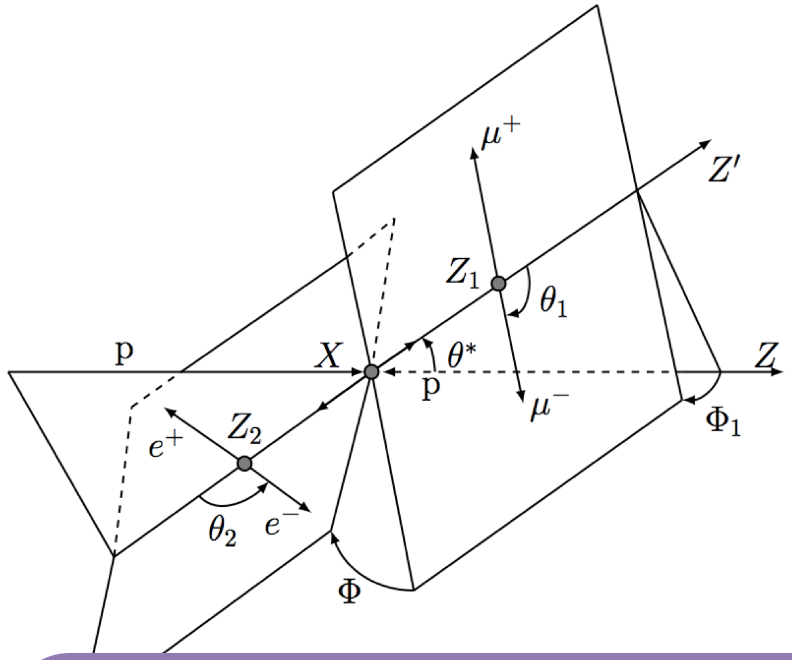
expect precision tests in R2 and beyond

*not 0.4 GeV, despite the compelling arguments being sent by email recently

guidance from Run 1

arXiv:1507.04548
ATLAS-CONF-2015-008





MV combination in ZZ channel
constrains 0^- with ~17 Higgs events

Tested Hypothesis	$p^{ALT}_{exp,\mu=1}$	$p^{ALT}_{exp,\mu=\hat{\mu}}$	p^{SM}_{obs}	p^{ALT}_{obs}	Obs. CL_S (%)
0^+_h	$2.5 \cdot 10^{-2}$	$4.7 \cdot 10^{-3}$	0.85	$7.1 \cdot 10^{-5}$	$4.7 \cdot 10^{-2}$
0^-	$1.8 \cdot 10^{-3}$	$1.3 \cdot 10^{-4}$	0.88	$< 3.1 \cdot 10^{-5}$	$< 2.6 \cdot 10^{-2}$
2^+	$4.3 \cdot 10^{-3}$	$2.9 \cdot 10^{-4}$	0.61	$4.3 \cdot 10^{-5}$	$1.1 \cdot 10^{-2}$
$2^+(\kappa_q = 0;\ p_T < 300)$	$< 3.1 \cdot 10^{-5}$	$< 3.1 \cdot 10^{-5}$	0.52	$< 3.1 \cdot 10^{-5}$	$< 6.5 \cdot 10^{-3}$
$2^+(\kappa_q = 0;\ p_T < 125)$	$3.4 \cdot 10^{-3}$	$3.9 \cdot 10^{-4}$	0.71	$4.3 \cdot 10^{-5}$	$1.5 \cdot 10^{-2}$
$2^+(\kappa_q = 2\kappa_g;\ p_T < 300)$	$< 3.1 \cdot 10^{-5}$	$< 3.1 \cdot 10^{-5}$	0.28	$< 3.1 \cdot 10^{-5}$	$< 4.3 \cdot 10^{-3}$
$2^+(\kappa_q = 2\kappa_g;\ p_T < 125)$	$7.8 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$	0.80	$7.3 \cdot 10^{-5}$	$3.7 \cdot 10^{-2}$

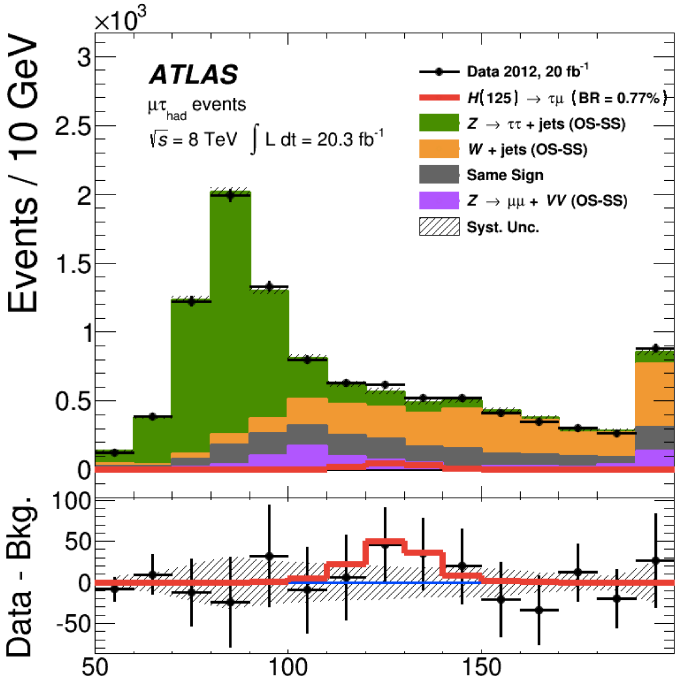
guidance from Run 1

arXiv:1508.07869
arXiv:1508.03372

BSM Higgs: flavor violation

mass window 110-150 GeV

- reconstructed width ~ 19 GeV with tau MMC
- small excess in Z-dominated channel



BR (H → μτ) < 1.85%

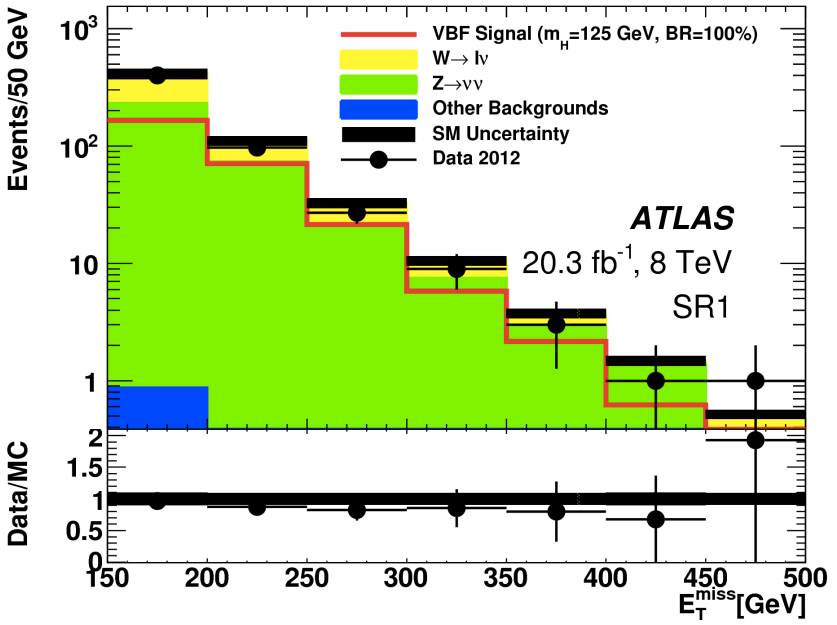
BSM Higgs: invisible decay

Indirect limit: < 0.23%

Direct search in low-background VBF channel: sensitivity ~ 31%

- 0.1% in SM: this is a WIMP search

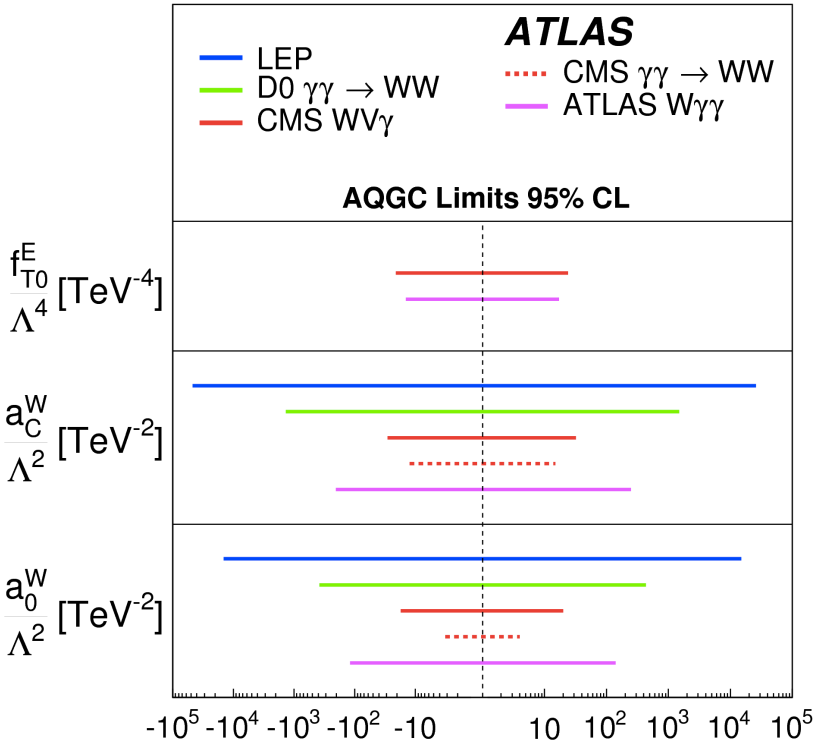
BR(H → inv.) < 0.31 (95% CL)

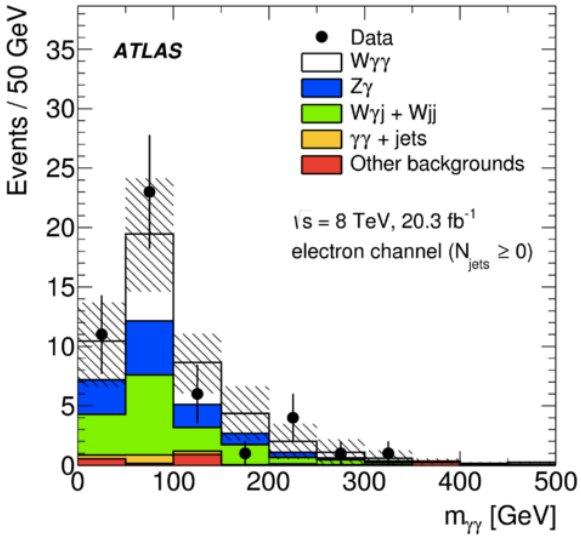


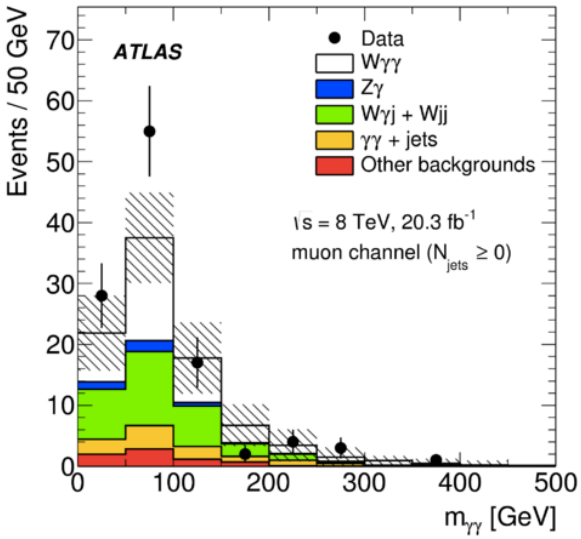
PRL 115 031802

guidance from Run 1

Electroweak physics: aQGCs



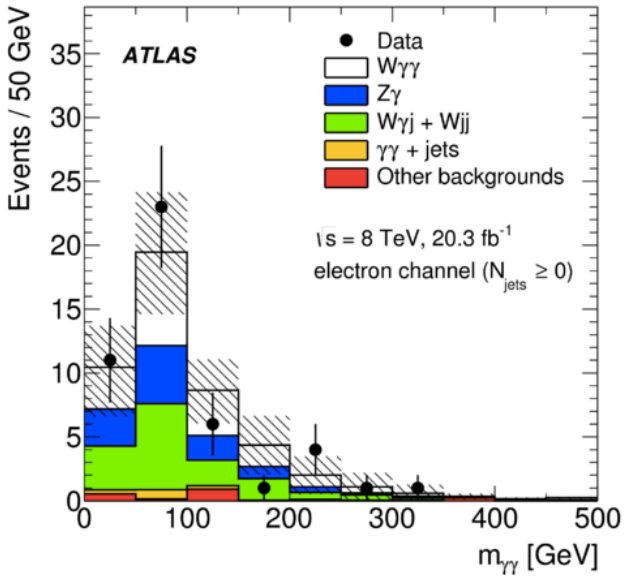


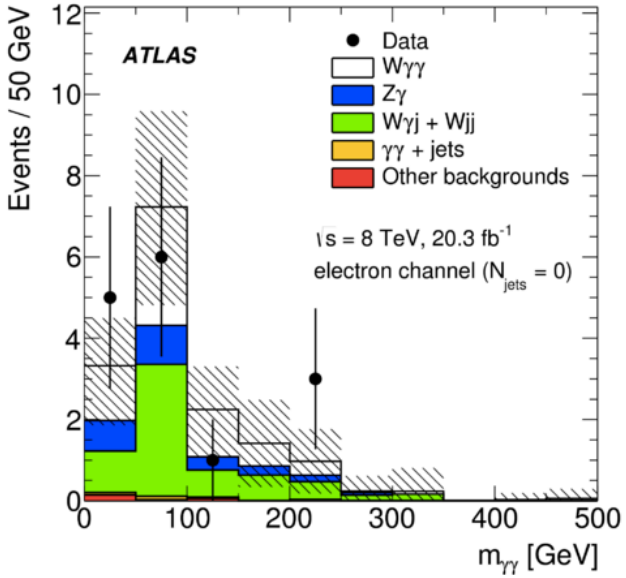


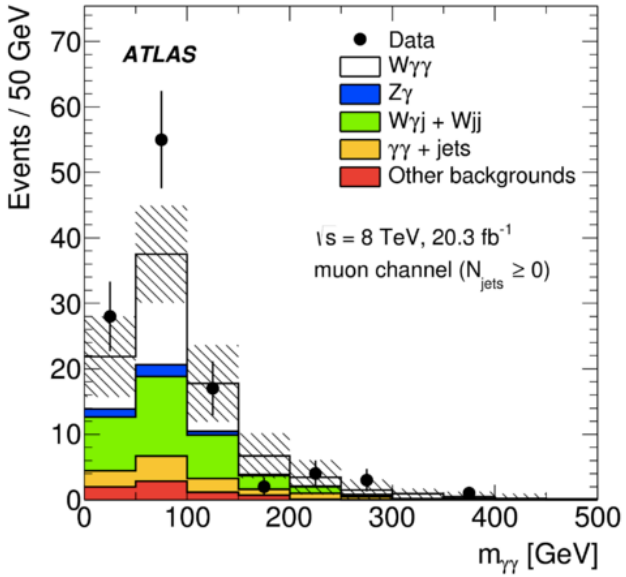
PRL 115 031802

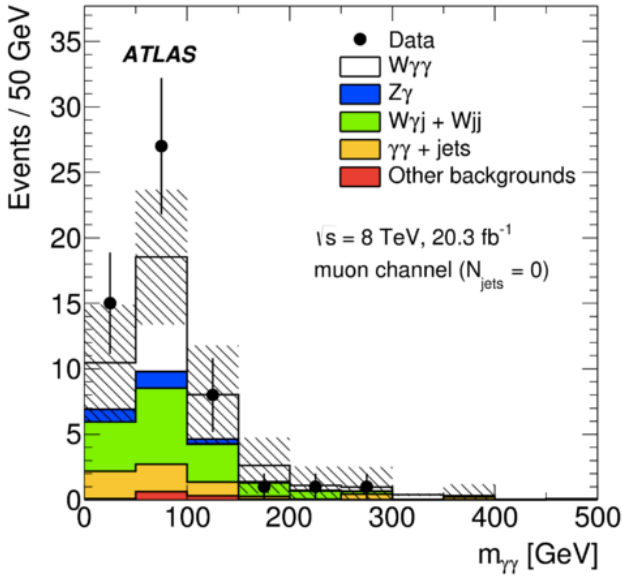
guidance from Run 1

Electroweak physics: Quartic couplings





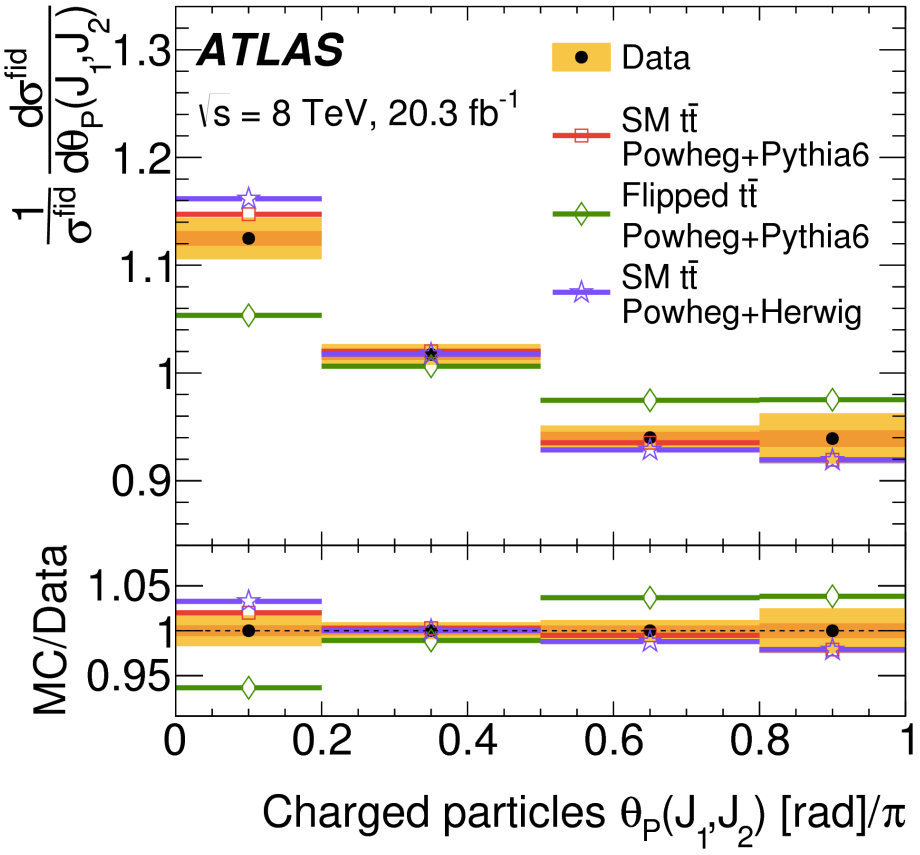




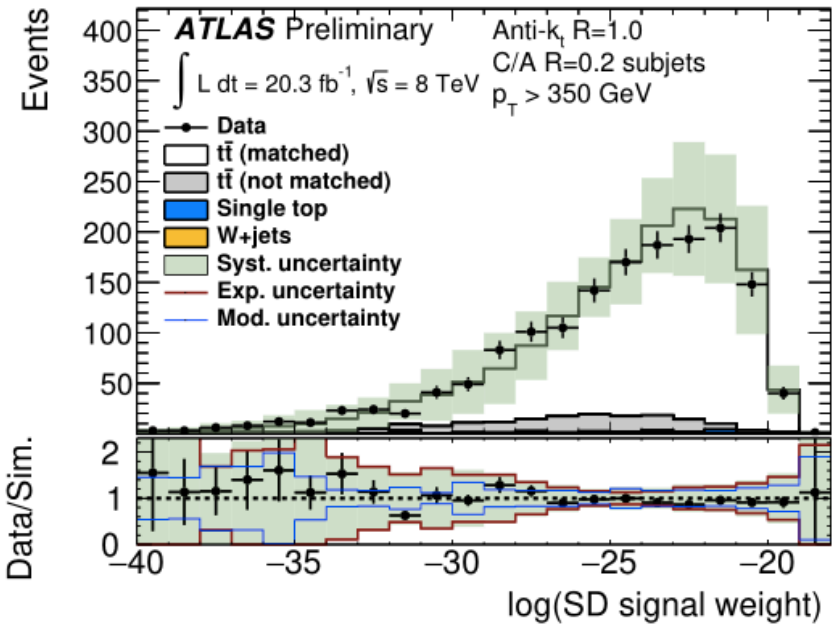
guidance from Run 1

PLB (2015) 475-493
ATLAS-CONF-2015-036

Color of W bosons



Tagging top jets



ATLAS calorimeter and tracker can both see in “color”

guidance from Run 1

PLB (2015) 475-493
ATLAS-CONF-2015-036

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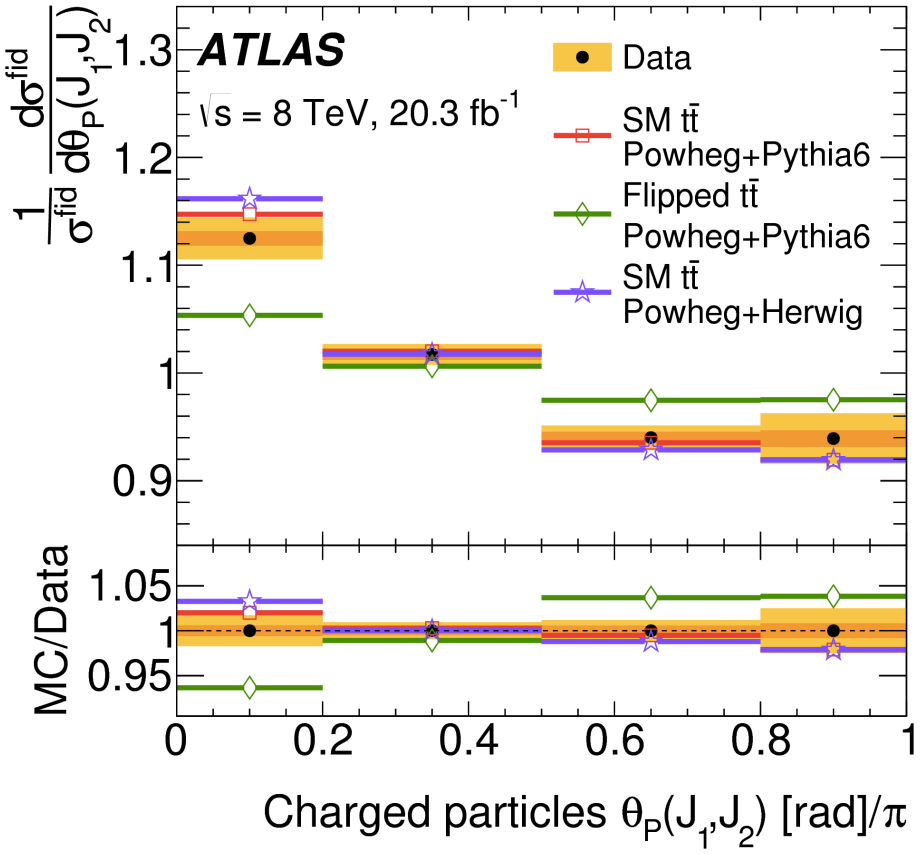

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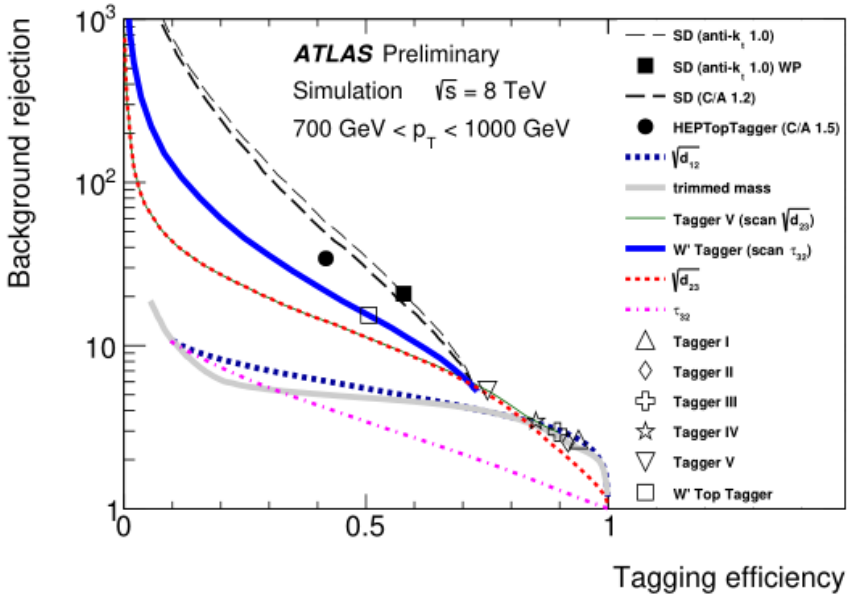
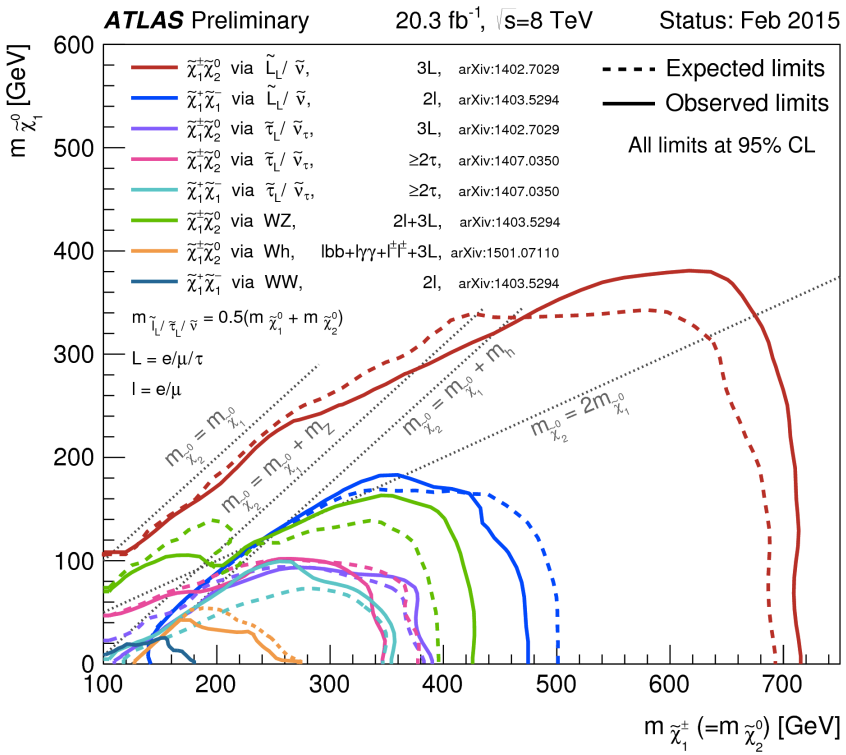
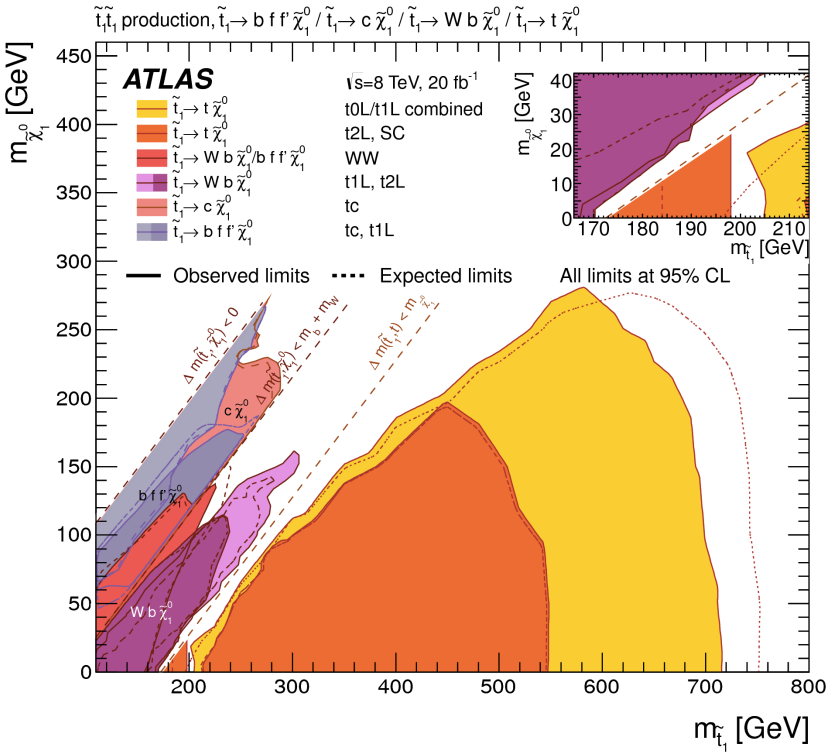


ATLAS calorimeter and tracker can both see in “color”

guidance from Run 1

Supersymmetry exclusion: combinations



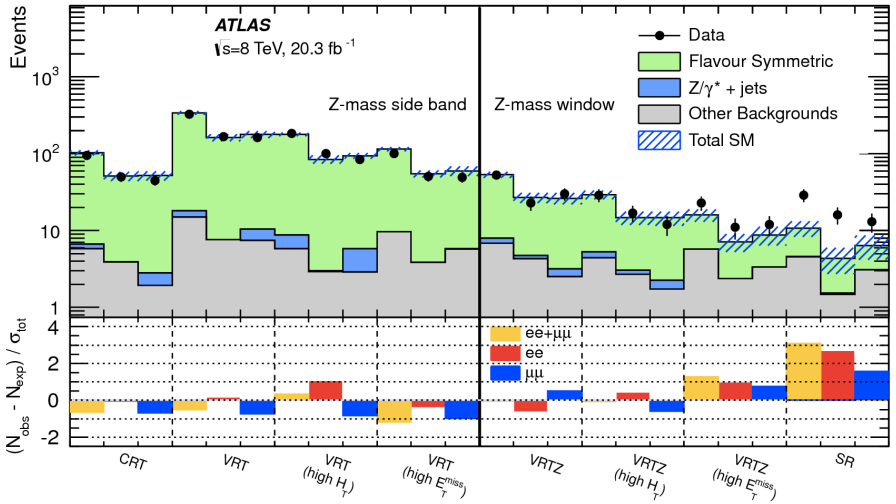


impressive (depressing?) exclusion in simplified models

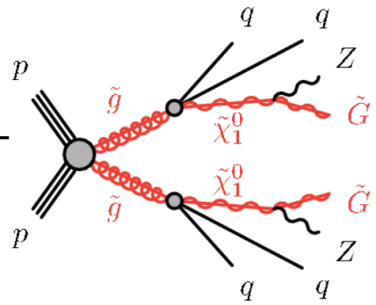
guidance from Run 1

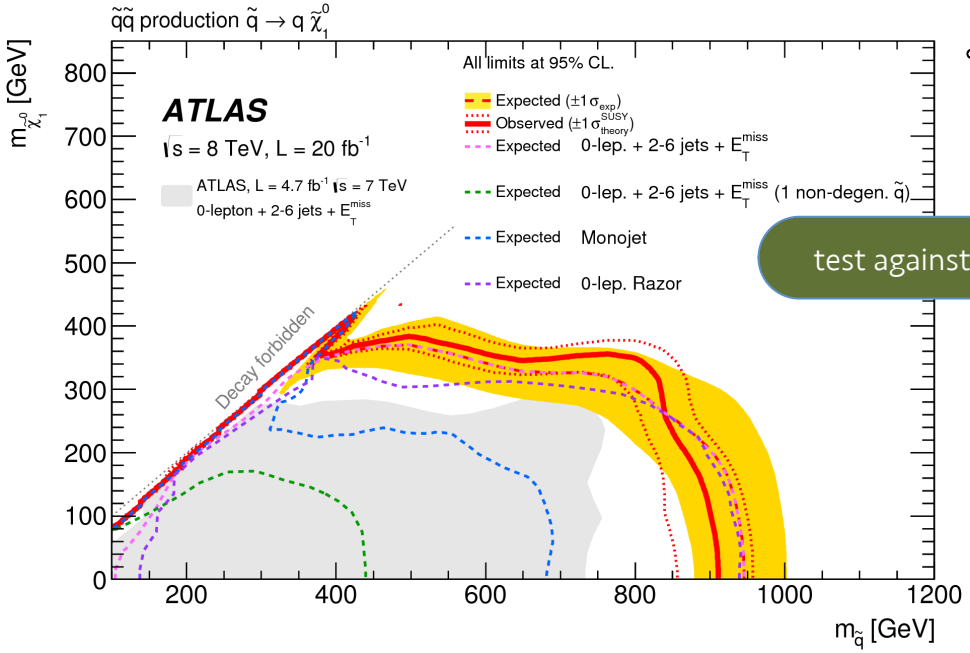
EPJC 75 2015 318
arXiv:1508.06608

Supersymmetry exclusion: optimism?

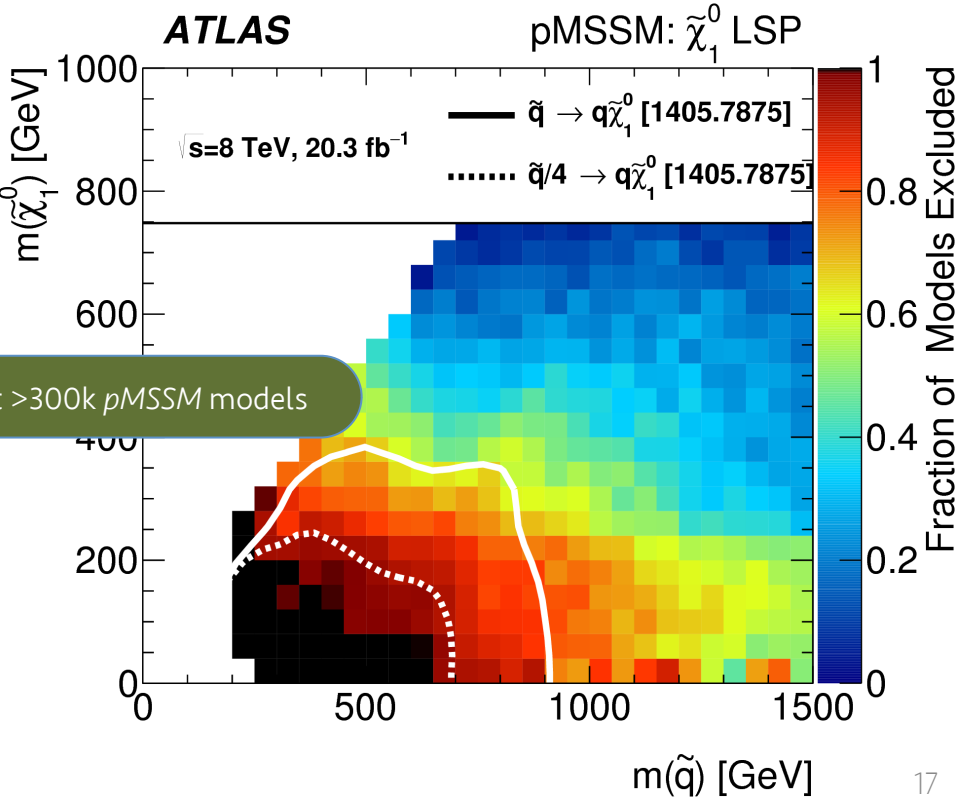


Excess in Z(ee)+jets+MET





test against >300k *pMSSM* models



guidance from Run 1

other models excluded

ATLAS Exotics Searches* - 95% CL Exclusion

Status: July 2015

ATLAS Preliminary

$\int \mathcal{L}\, dt$ = (4.7 - 20.3) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	ℓ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt$[fb^{-1}]	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	20.3	M_D 5.25 TeV	$n = 2$	1502.01518
	ADD non-resonant $\ell\ell$	2e,μ	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\rightarrow \ell q$	1 e,μ	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	20.3	M_{th} 5.82 TeV	$n = 6$	1407.1376
	ADD BH high N_{trk}	2 μ (SS)	–	–	20.3	M_{th} 4.7 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	≥ 1 e,μ	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1405.4254
	ADD BH high multijet	–	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1503.08988
	RS1 $G_{KK} \rightarrow \ell\ell$	2 e,μ	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \rightarrow \gamma\gamma$	2 γ	–	–	20.3	G_{KK} mass 2.66 TeV	$k/\overline{M}_{Pl} = 0.1$	1504.05511
	Bulk RS $G_{KK} \rightarrow ZZ \rightarrow qq\ell\ell$	2 e,μ	2 j / 1 J	–	20.3	G_{KK} mass 740 GeV	$k/\overline{M}_{Pl} = 1.0$	1409.6190
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	1 e,μ	2 j / 1 J	Yes	20.3	W' mass 760 GeV	$k/\overline{M}_{Pl} = 1.0$	1503.04677
	Bulk RS $G_{KK} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$	–	4 b	–	19.5	G_{KK} mass 500-720 GeV	$k/\overline{M}_{Pl} = 1.0$	1506.00285
	Bulk RS $g_{KK} \rightarrow t\bar{t}$	1 e,μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	2 e,μ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	KK mass 960 GeV		1504.04605
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	2 e,μ	–	–	20.3	Z' mass 2.9 TeV		1405.4123
	SSM $Z' \rightarrow \tau\tau$	2 τ	–	–	19.5	Z' mass 2.02 TeV		1502.07177
	SSM $W' \rightarrow \ell\nu$	1 e,μ	–	Yes	20.3	W' mass 3.24 TeV		1407.7494
	EGM $W' \rightarrow WZ \rightarrow \ell\nu\ell'\ell'$	3 e,μ	–	Yes	20.3	W' mass 1.52 TeV		1406.4456
	EGM $W' \rightarrow WZ \rightarrow qq\ell\ell$	2 e,μ	2 j / 1 J	–	20.3	W' mass 1.59 TeV		1409.6190
	EGM $W' \rightarrow WZ \rightarrow qqqq$	–	2 J	–	20.3	W' mass 1.3-1.5 TeV		1506.00962
	HVT $W' \rightarrow WH \rightarrow \ell\nu bb$	1 e,μ	2 b	Yes	20.3	W' mass 1.47 TeV	$g_V = 1$	1503.08089
	LRSM $W'_R \rightarrow t\bar{b}$	1 e,μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \rightarrow t\bar{b}$	0 e,μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	17.3	Λ 12.0 TeV	$\eta_{LL} = -1$	1504.00357
	CI $qq\ell\ell$	2 e,μ	–	–	20.3	Λ 21.6 TeV	$\eta_{LL} = -1$	1407.2410
	CI $uutt$	2 e,μ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	Λ 4.3 TeV	$\lvert C_{LL} \rvert = 1$	1504.04605
DM	EFT D5 operator (Dirac)	0 e,μ	≥ 1 j	Yes	20.3	M_* 974 GeV	at 90% CL for $m(\chi) < 100$ GeV	1502.01518
	EFT D9 operator (Dirac)	0 e,μ	1 J, ≤ 1 j	Yes	20.3	M_* 2.4 TeV	at 90% CL for $m(\chi) < 100$ GeV	1309.4017
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	20.3	LQ mass 1.05 TeV	$\beta = 1$	Preliminary
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	20.3	LQ mass 1.0 TeV	$\beta = 1$	Preliminary
	Scalar LQ 3rd gen	1 e,μ	≥1 b, ≥3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	Preliminary
Heavy quarks	VLQ $TT \rightarrow Ht + X$	1 e,μ	≥ 2 b, ≥ 3 j	Yes	20.3	T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \rightarrow Wb + X$	1 e,μ	≥ 1 b, ≥ 3 j	Yes	20.3	Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \rightarrow Hb + X$	1 e,μ	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \rightarrow Zb + X$	2/≥3 e,μ	≥2/≥1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	$T_{5/3} \rightarrow Wt$	1 e,μ	≥ 1 b, ≥ 5 j	Yes	20.3	$T_{5/3}$ mass 840 GeV		1503.05425
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1 γ	1 j	–	20.3	q^* mass 3.5 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1309.3230
	Excited quark $q^* \rightarrow qg$	–	2 j	–	20.3	q^* mass 4.09 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1407.1376
	Excited quark $b^* \rightarrow Wt$	1 or 2 e,μ	1 b, 2 j or 1 j	Yes	4.7	b^* mass 870 GeV	left-handed coupling	1301.1583
	Excited lepton $\ell^* \rightarrow \ell\gamma$	2 e,μ, 1 γ	–	–	13.0	ℓ^* mass 2.2 TeV	$\Lambda = 2.2$ TeV	1308.1364
	Excited lepton $\nu^* \rightarrow \ell W, \nu Z$	3 e,μ,τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \rightarrow W\gamma$	1 e,μ, 1 γ	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e,μ	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	2 e,μ (SS)	–	–	20.3	$H^{\pm\pm}$ mass 551 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\ell$)=1	1412.0237
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	3 e,μ,τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e,μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{non-res} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1g_D$, spin 1/2	Preliminary

$\sqrt{s}$ = 7 TeV $\sqrt{s}$ = 8 TeV

10^{-1} 1 10 **Mass scale [TeV]**

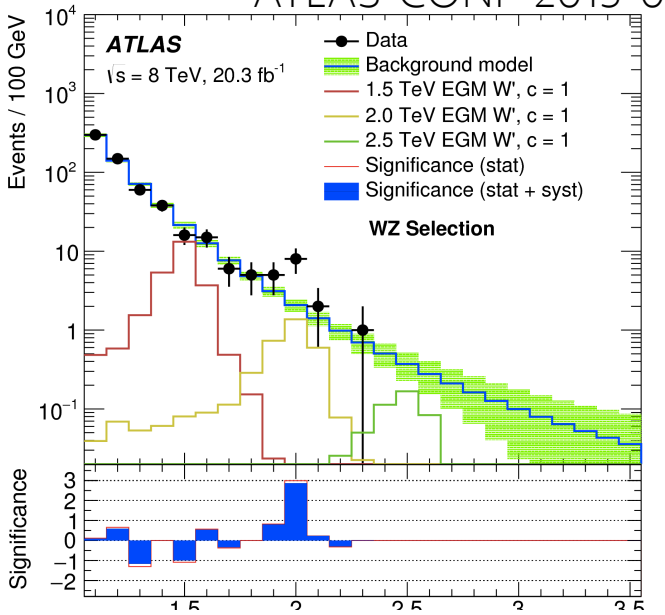
*Only a selection of the available mass limits on new states or phenomena is shown.

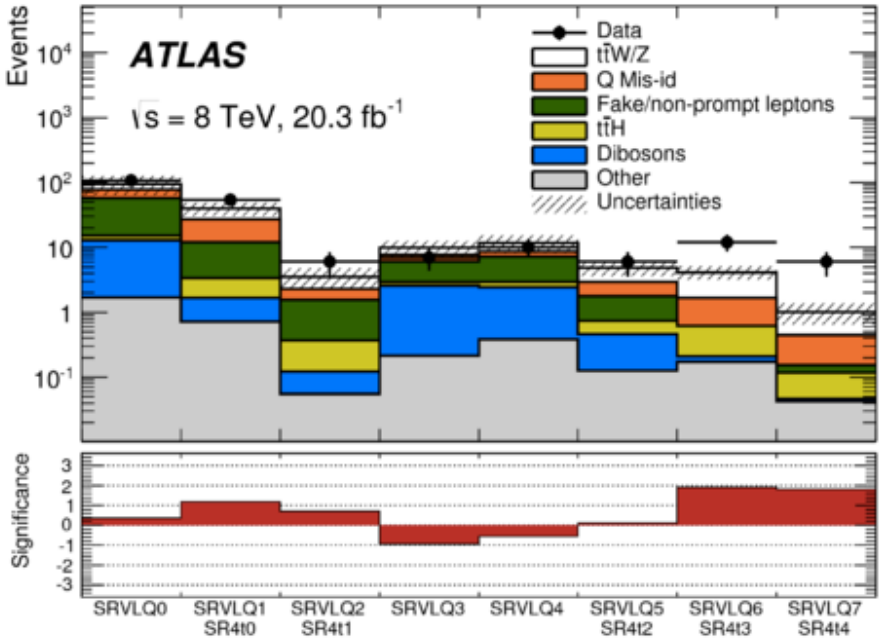
guidance from Run 1

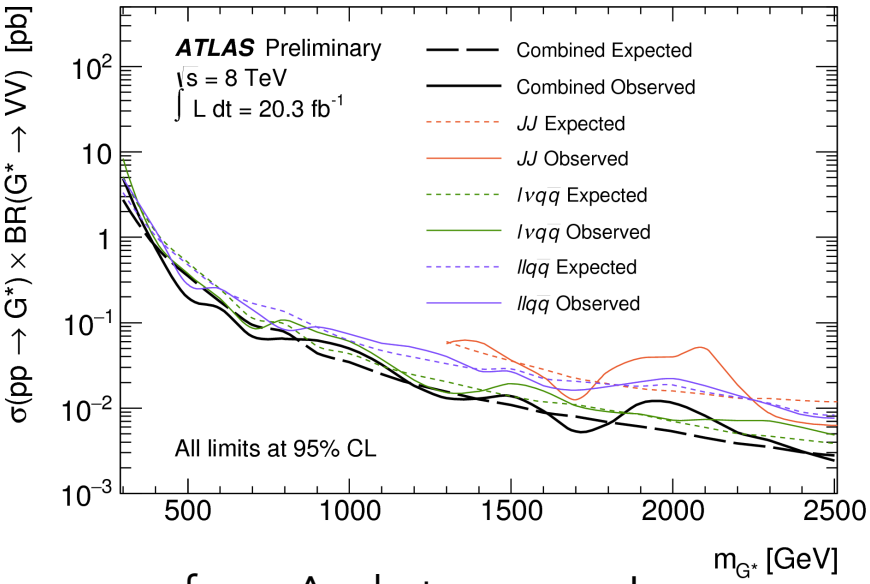
other models: optimism?

- No significant deviations from SM identified:
  - but a few small excesses to build excitement for Run 2

arXiv:1506.00962
arXiv:1504.04605
ATLAS-CONF-2015-045



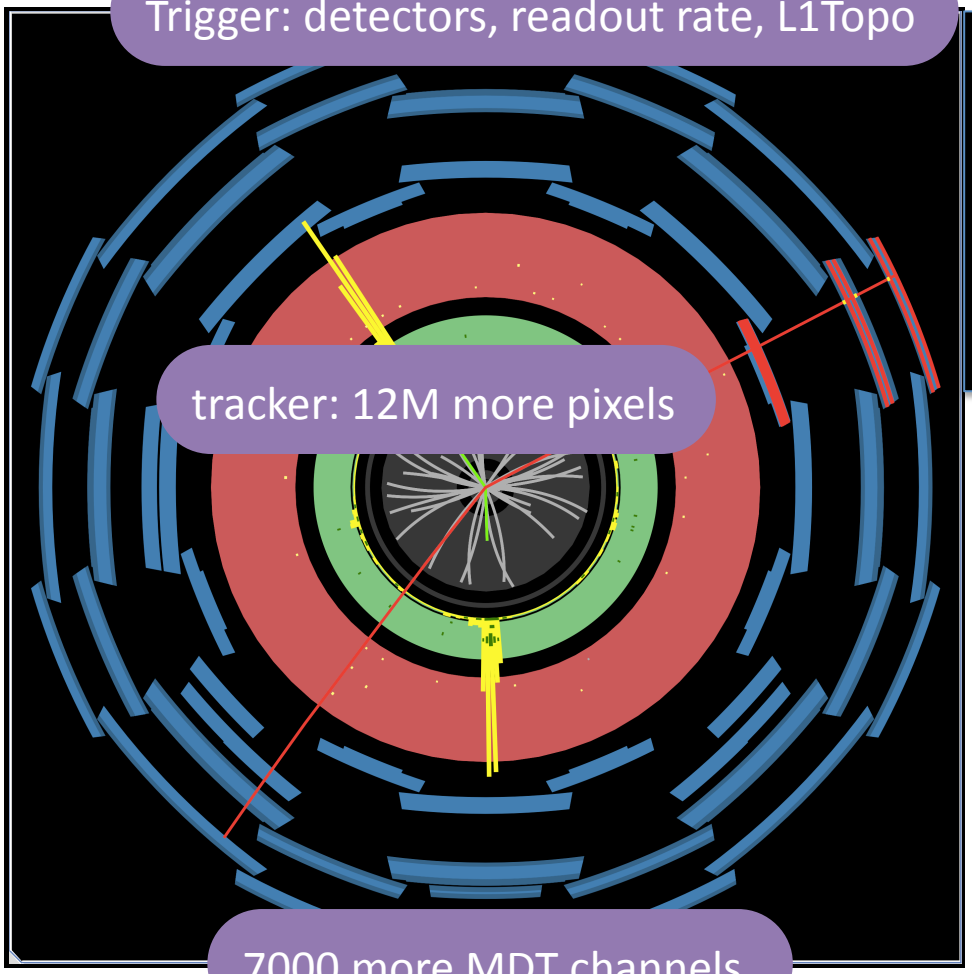




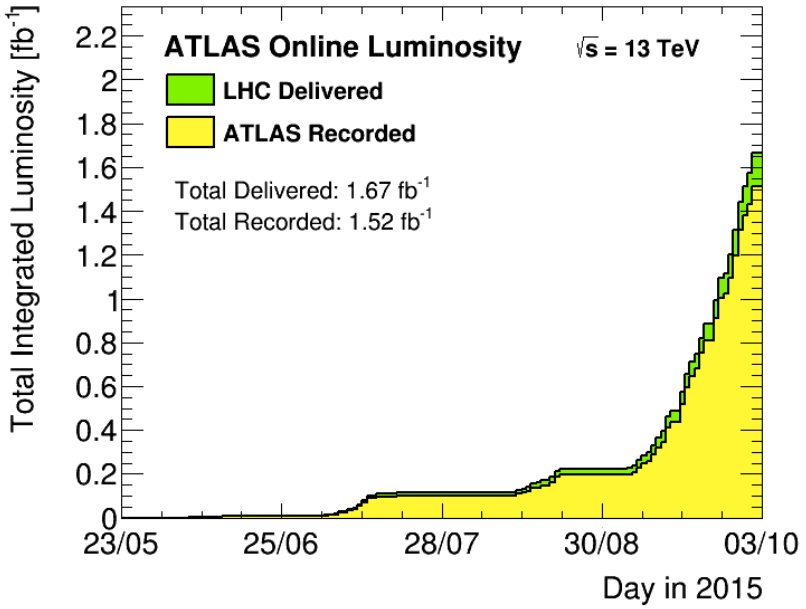
more from Andy tomorrow!

RUN 2 PREPARATIONS

run 2 preparations: what's new?

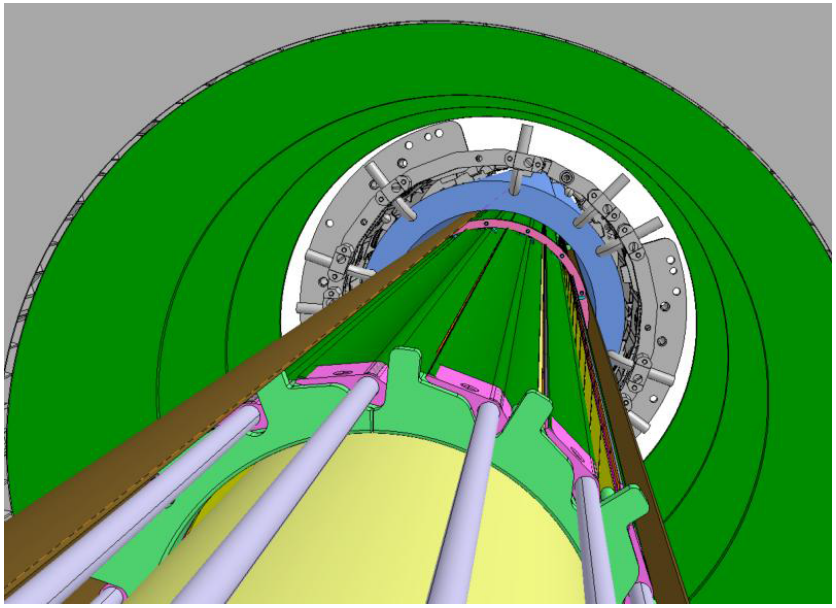


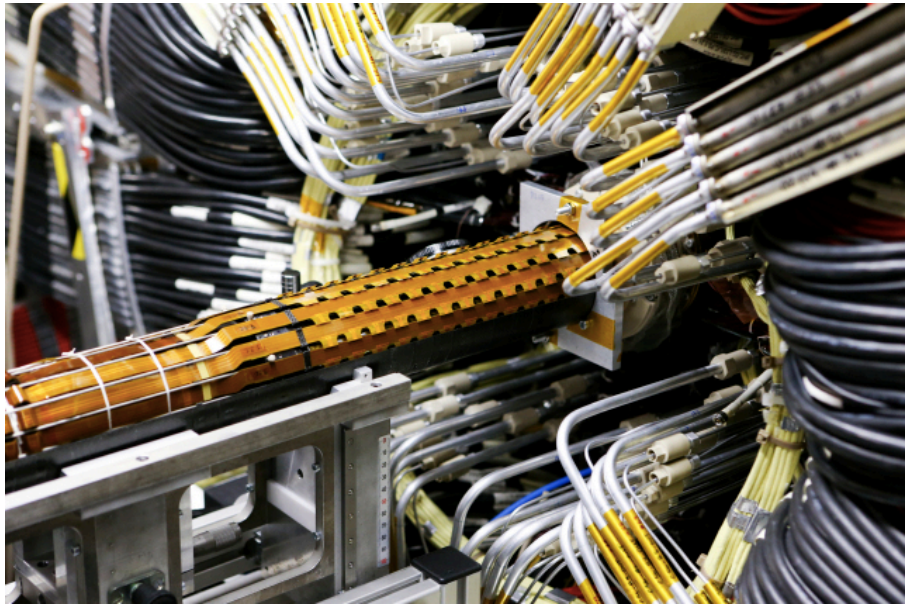
Status: June 2015
muon subsystems: >97%
Tile calorimeter 99%
EM Barrel calorimeter 100%
Tracker: 97%(TRT) 99%(Si) 99%(Pixel)



run 2 preparations: what's new?

- Tracker upgrade and consolidation
  - New beampipe and IBL pixel detector
    - cope with growing BL inefficiency → double the fake b-tag rate at high pileup
  - Reduced ID material with new service quarter panels





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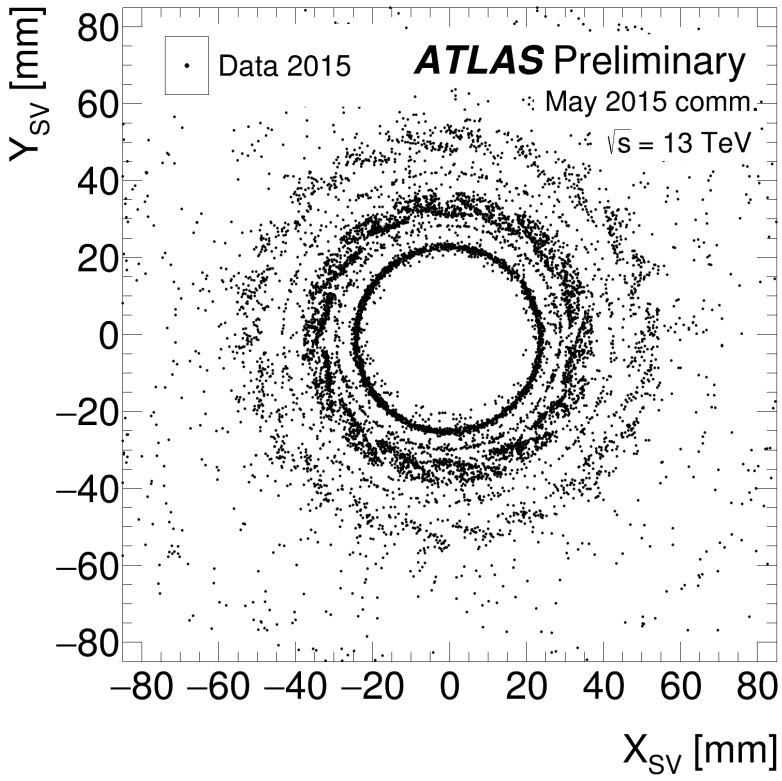
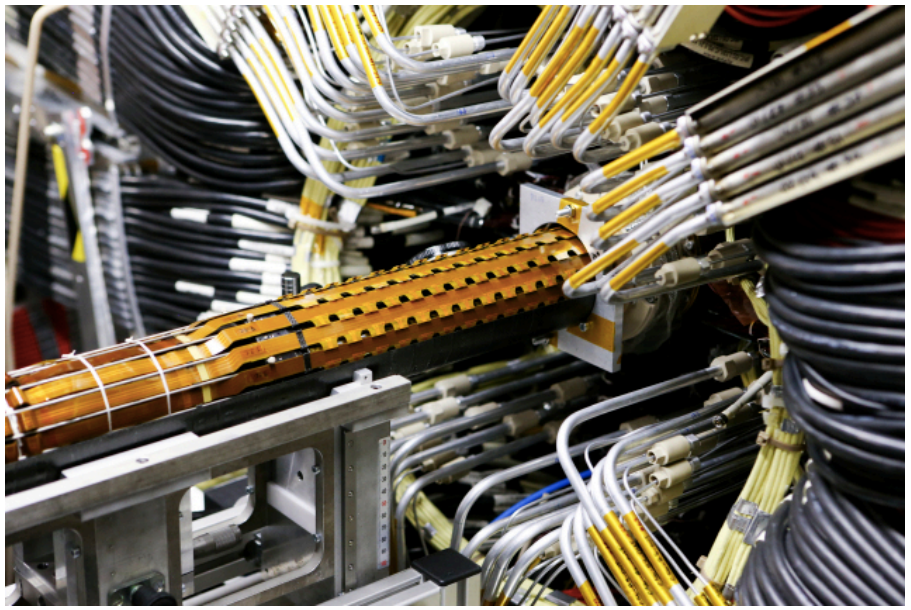
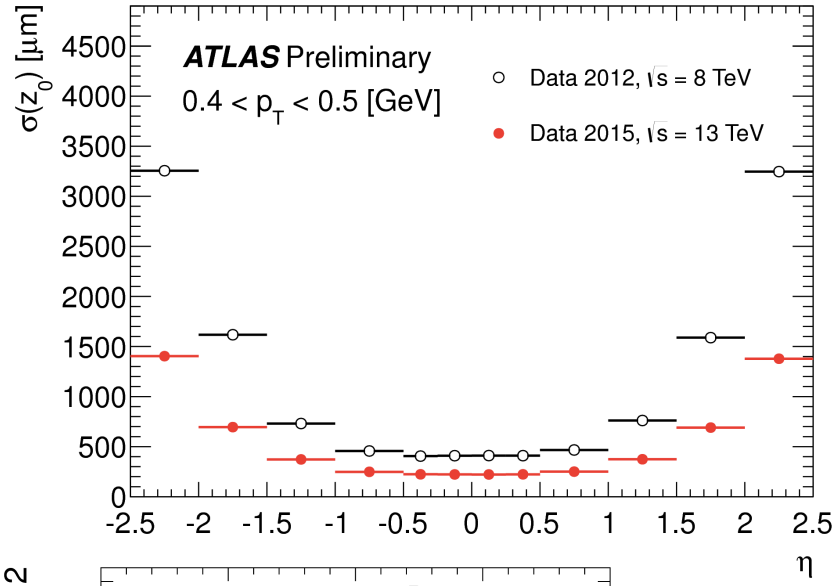
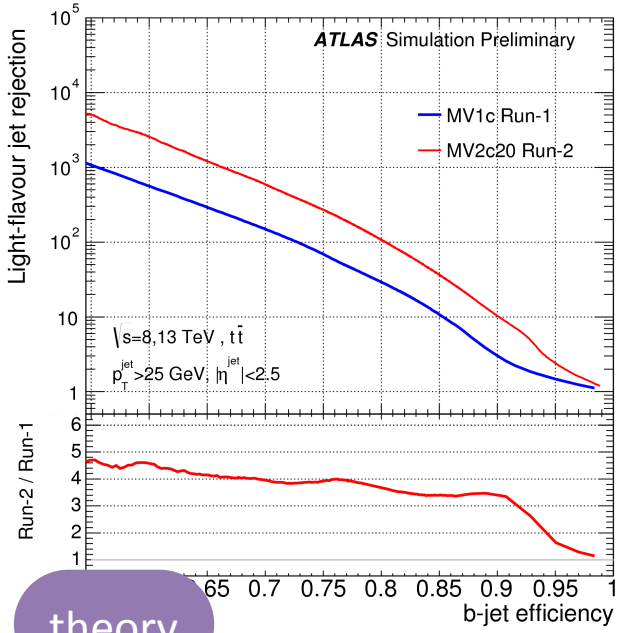




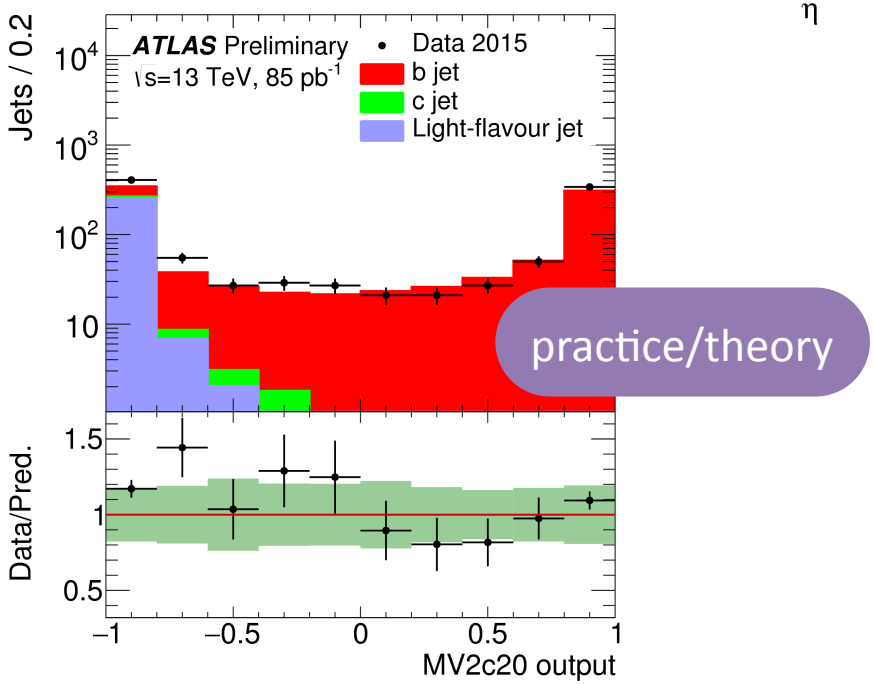
run 2 preparations: what's new?

- vertexing improvement from tracker upgrade:
  - smaller pixels: better pileup vertex reconstruction
  - 4 times less background in b-tagging





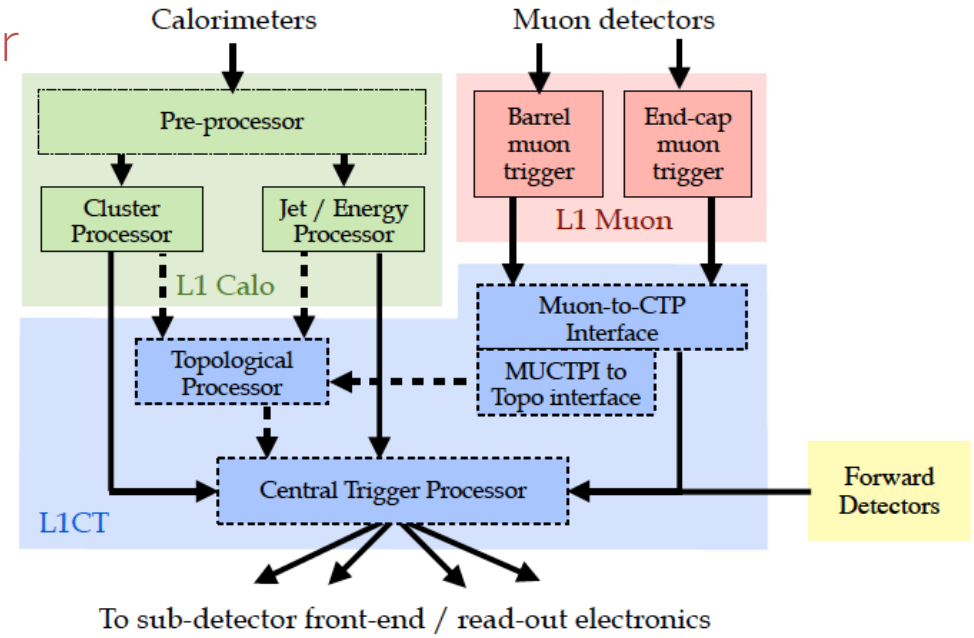
theory



practice/theory

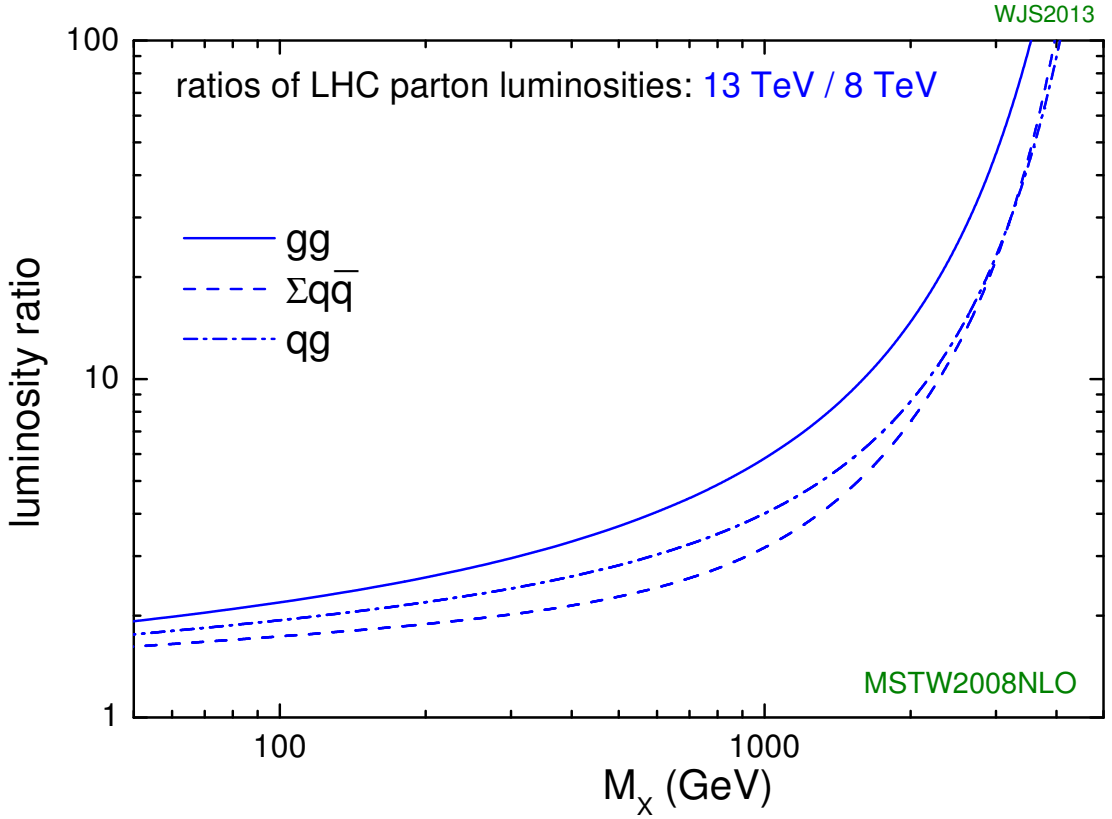
run 2 preparations: what's new?

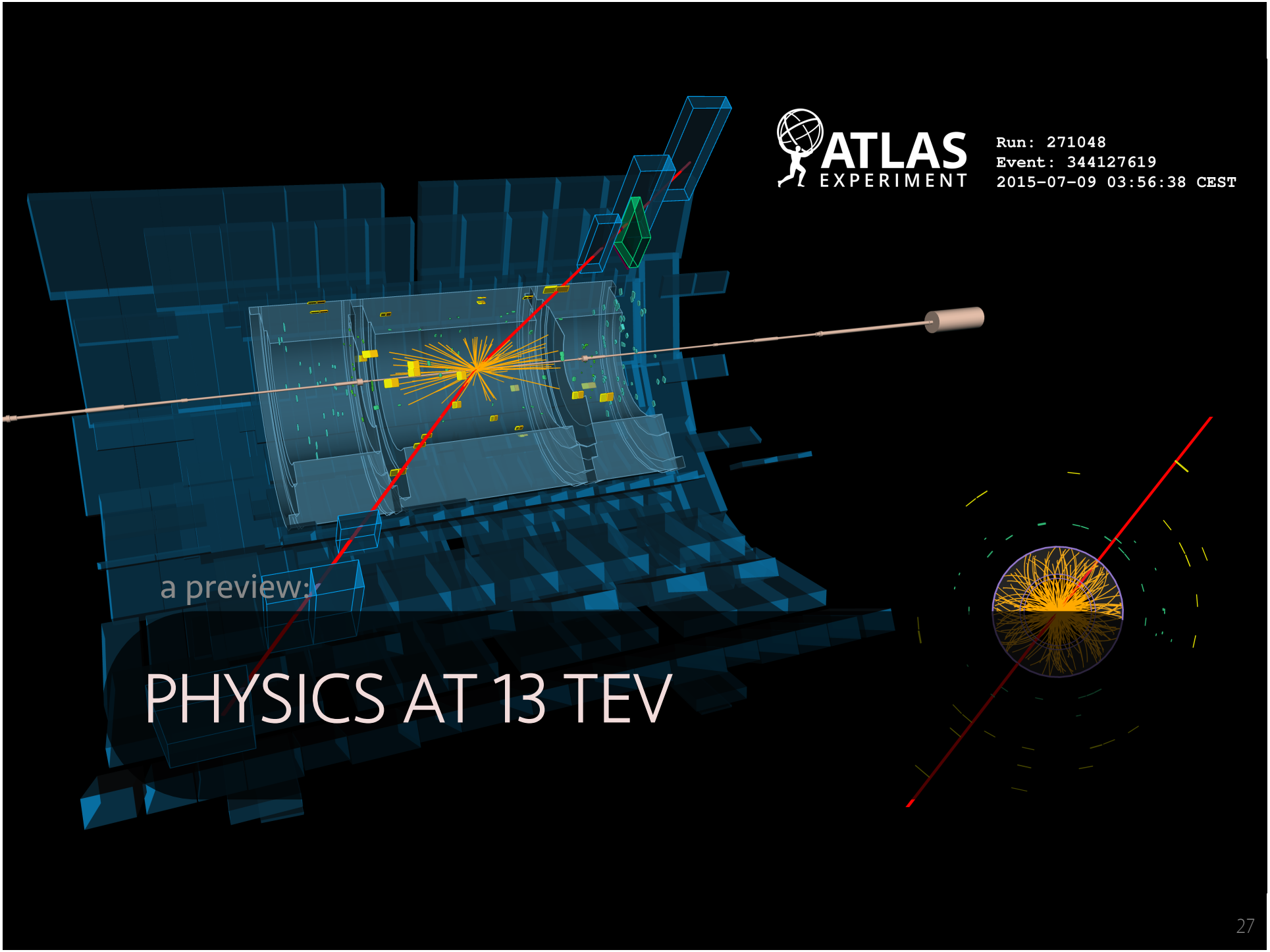
- L1 trigger hardware improvements:
  - replacement minimum bias trigger detector (η to 3.75)
- L1 trigger upgrades (preserve low thresholds):
  - topological processor combines L1 calorimeter and muon (isolation, invariant mass)
  - new CTP: double the "menu"
  - rate increases to 100 kHz
- HLT improvements and reorganization



run 2 preparations: what's new?

- 13 TeV collisions – improved physics prospects in Run 2
  - Statistical sensitivity for mass scales 2-3 TeV can be matched with few /fb
    - assuming similar uncertainties
  - limits in favorable scenarios are already surpassed!

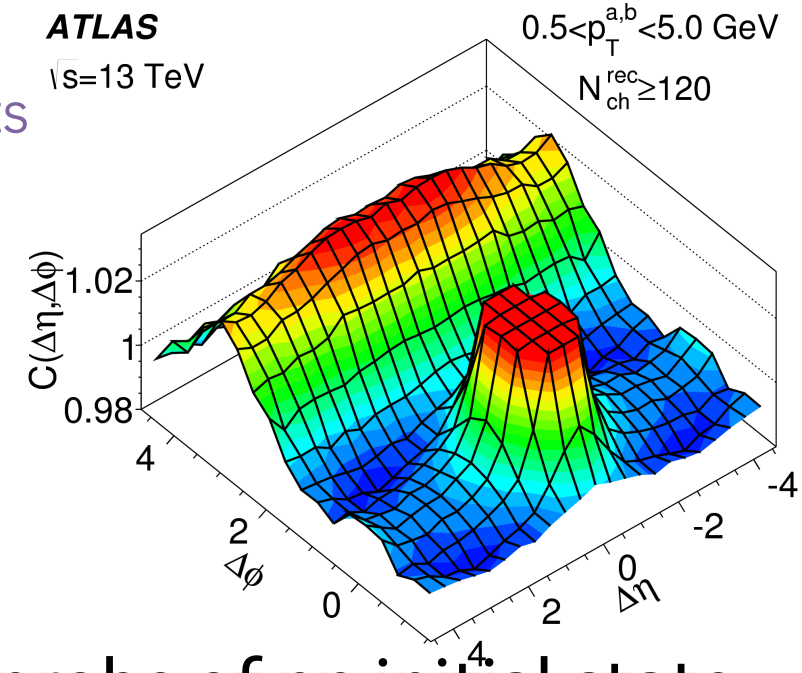


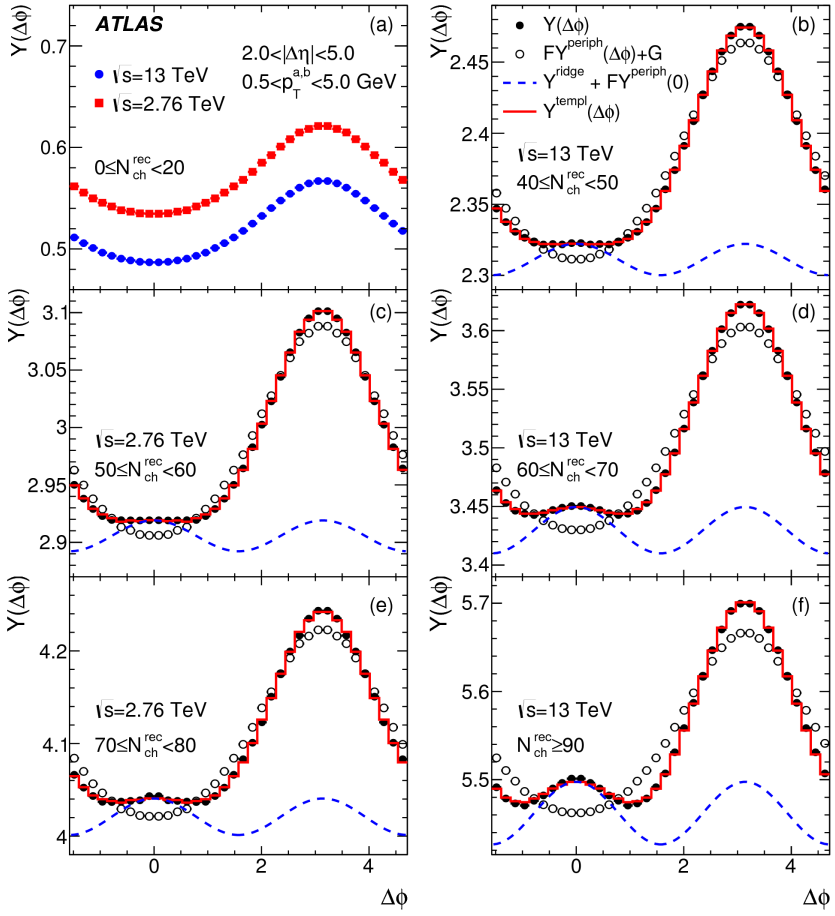

ATLAS
EXPERIMENT
Run: 271048
Event: 344127619
2015-07-09 03:56:38 CEST
a preview:
PHYSICS AT 13 TEV

physics at 13 TeV

high hadron multiplicity pp events

arXiv:1509.04776





- probe of pp initial state
- Compare 13 TeV pp to 2.76 TeV
  - "ridge" in di-hadron angular correlations: same at 13 TeV
  - consistent with a hadron anisotropy

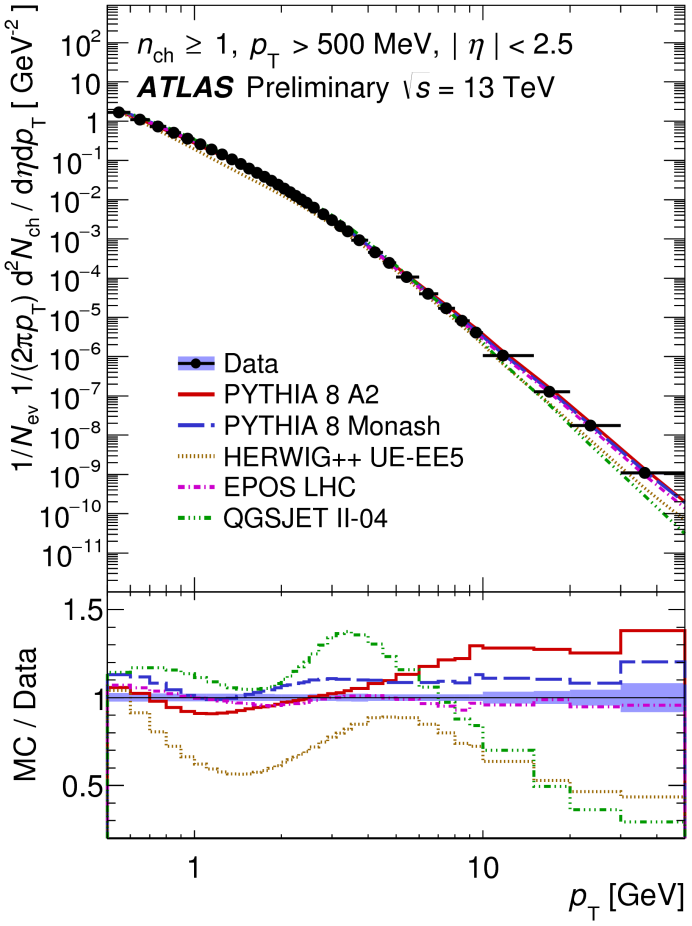
First 13 TeV ATLAS paper submitted!

ATLAS-CONF-2015-026

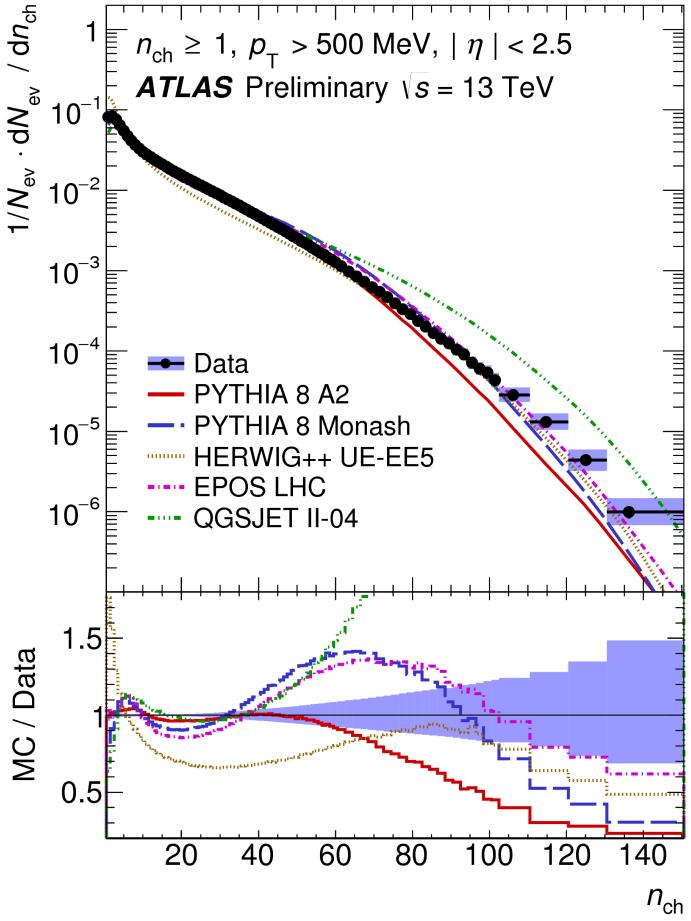
physics at 13 TeV

minimum bias studies

charged particle spectrum



multiplicity distribution

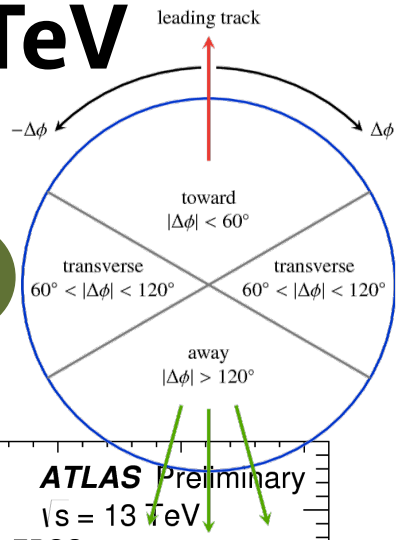


Generators tuned to MB+UE perform well

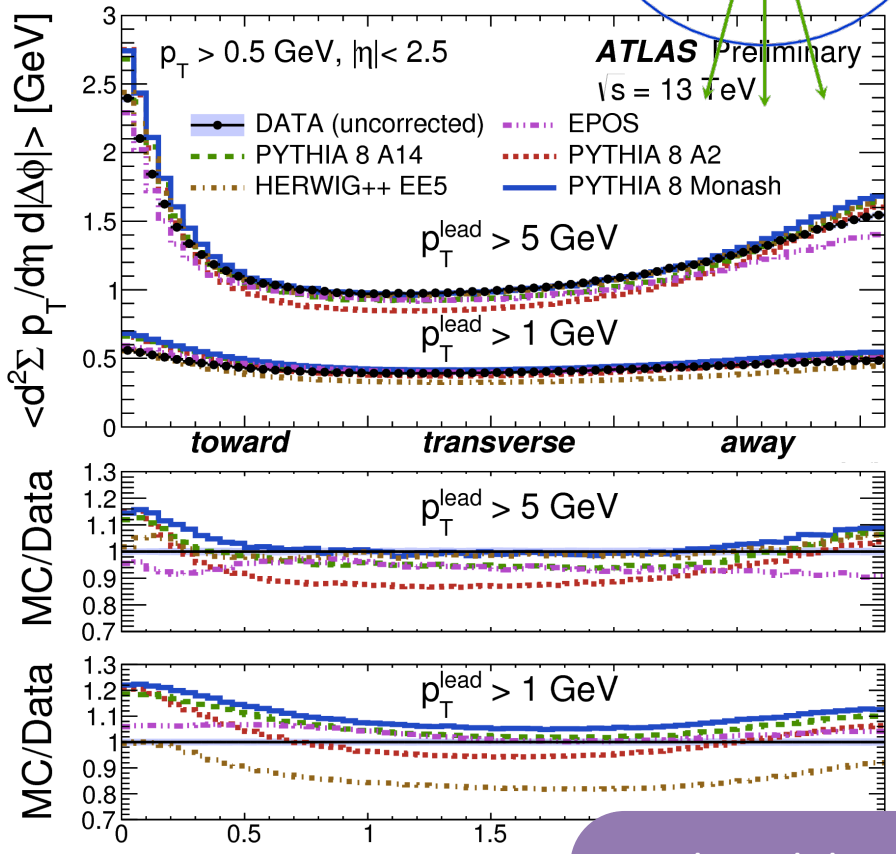
ATL-PHYS-PUB-2015-019

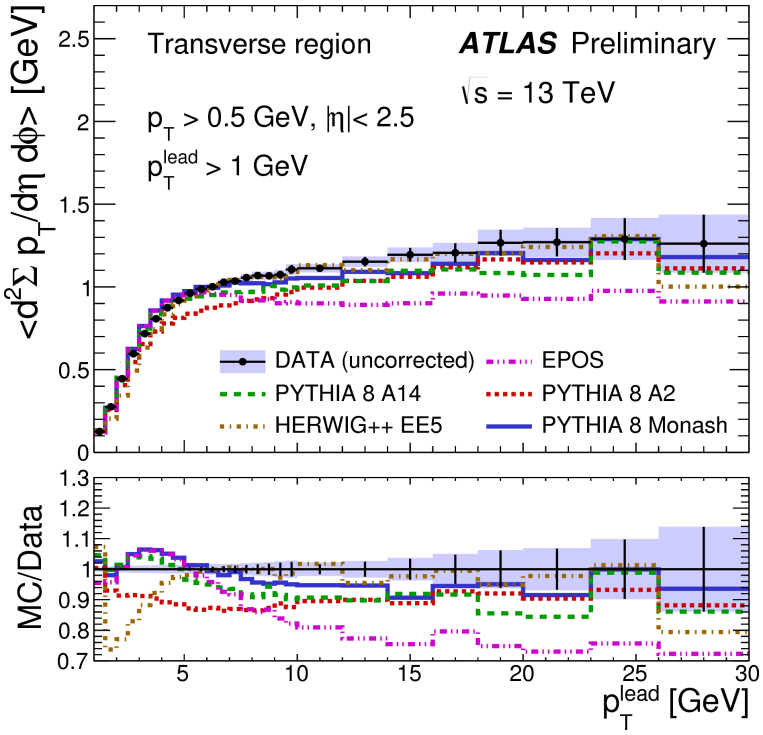
physics at 13 TeV

underlying event



- Average track p_T density vs. leading track p_T



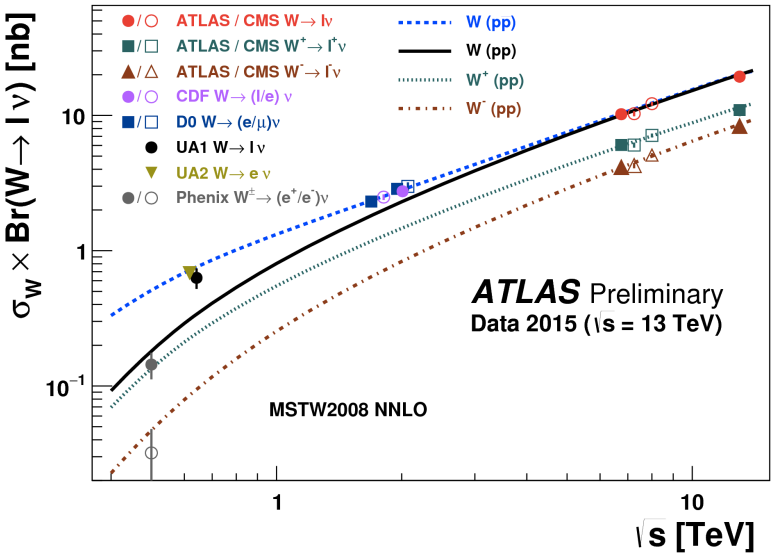


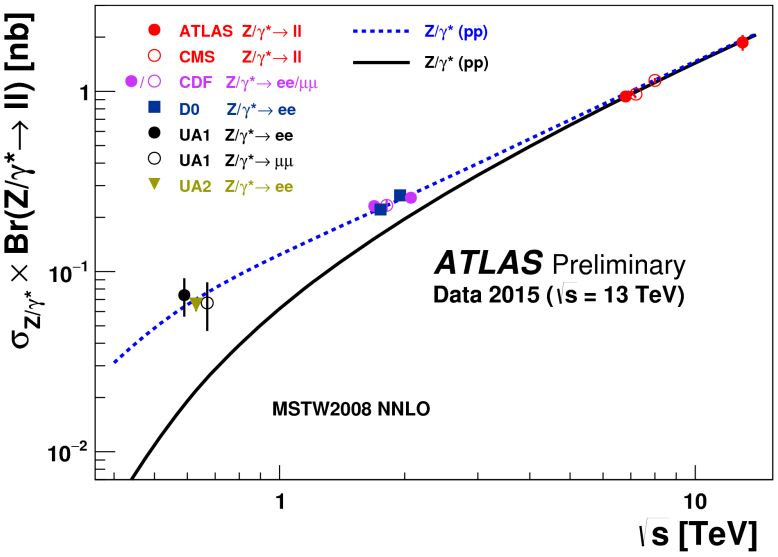
good modeling by generators tuned to LHC U.E. data

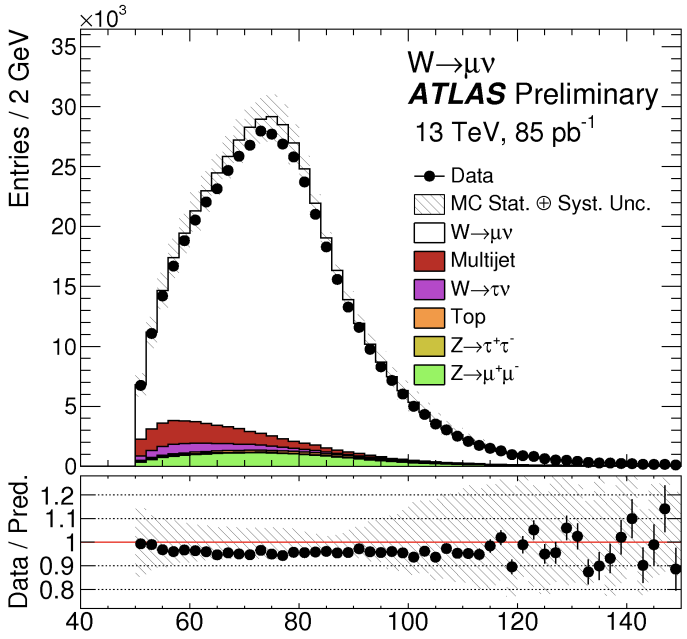
physics at 13 TeV

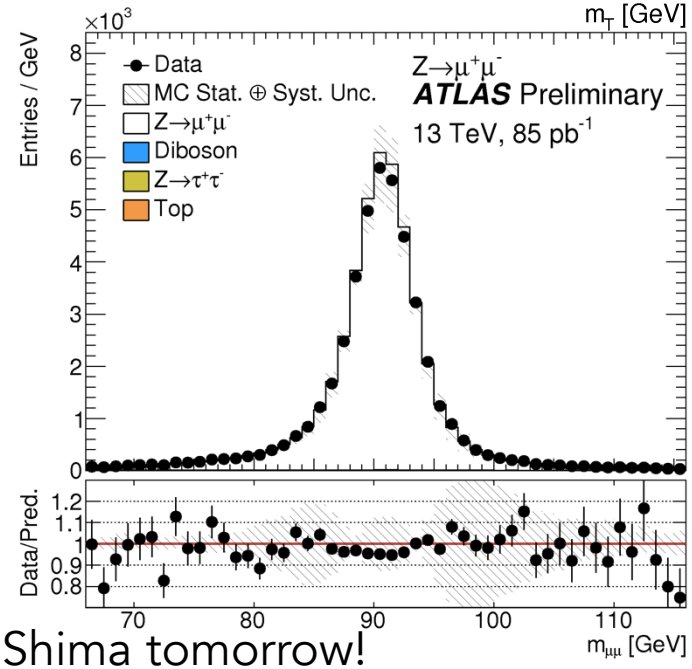
W and Z production

ATL-CONF-2015-039









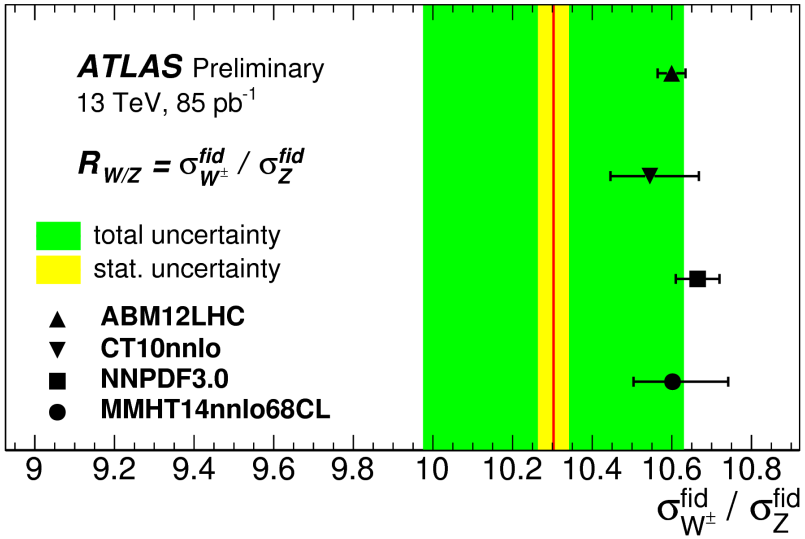
more from Shima tomorrow!

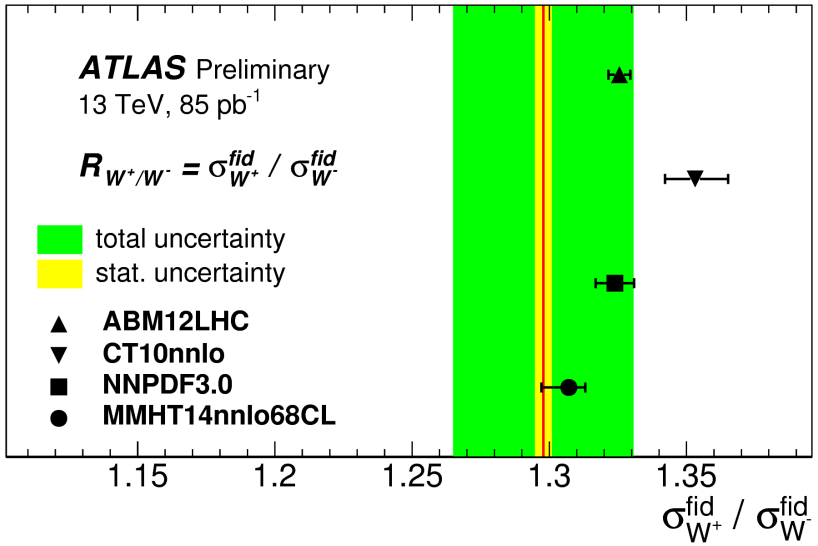
ATLAS-CONF-2015-039

physics at 13 TeV

W and Z production

- NNLO + several PDF sets agree with data (within uncertainty: 9% luminosity)
- Ratios already useful:
  - note differences among PDF set predictions
    - CT10nnlo did not include LHC





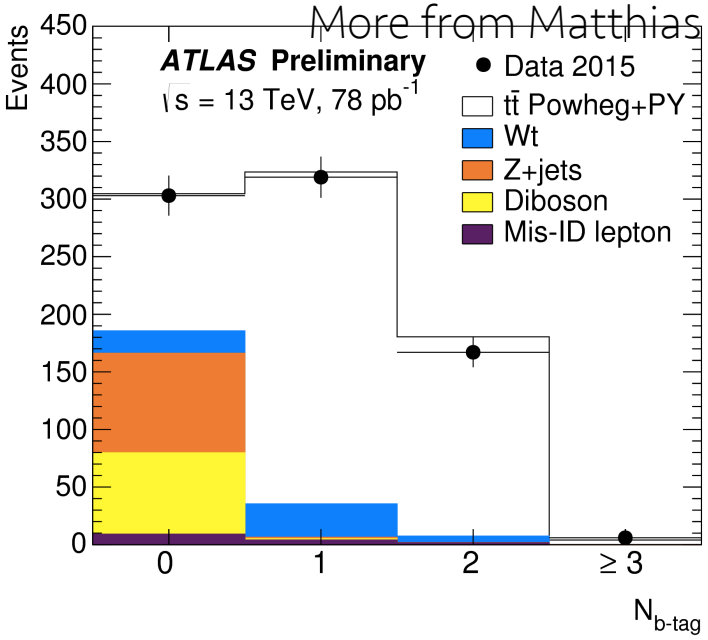
physics at 13 TeV

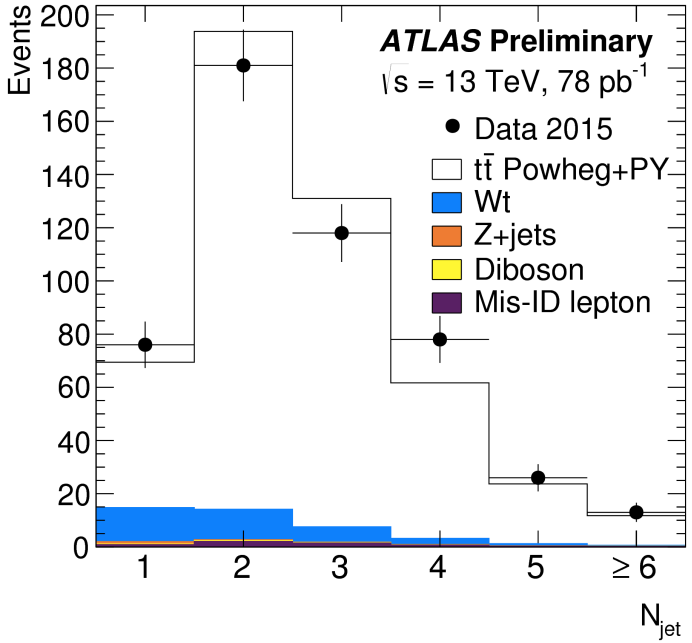
top pair production

- First 13 TeV measurement uses high purity (< 10%) channel:
  - e + μ + 1 or more b-jets
  - 486 events: simultaneously fit b-tag probability and cross section
- 825 ± 49 ± 60 ± 83 (lumi) pb
  - Systematics dominated (top factory!):
    - shower modeling uncertainty
    - Electron ID efficiency
      - will improve with Z statistics

ATLAS-CONF-2015-033

More from Matthias today!



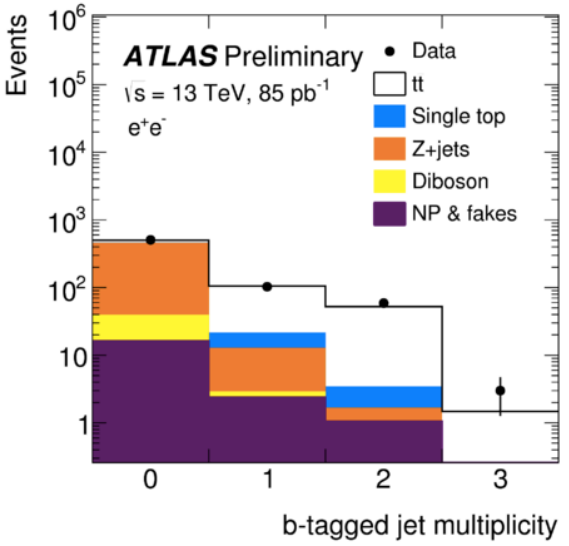


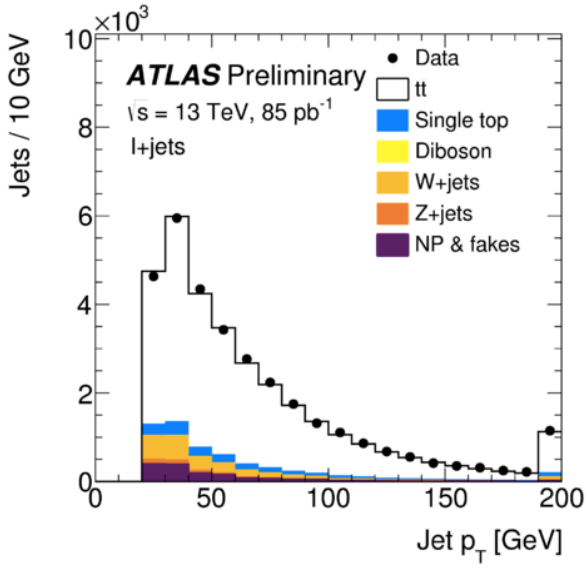
ATLAS-CONF-2015-049

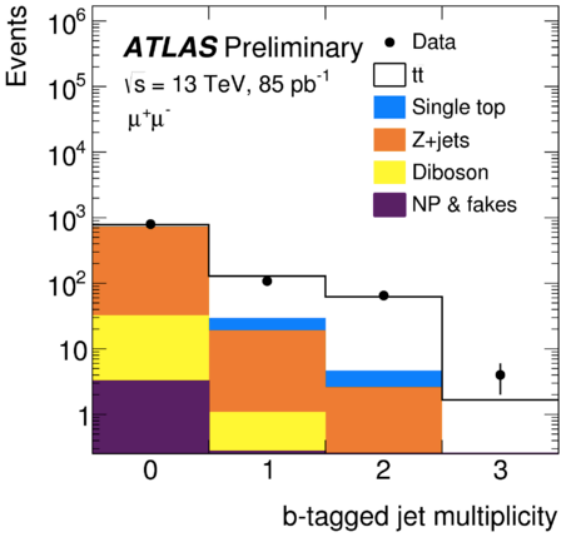
physics at 13 TeV

top pair production

- add missing lepton channels (single-lepton and same-flavor)
  - higher statistics
  - similar dominant uncertainties



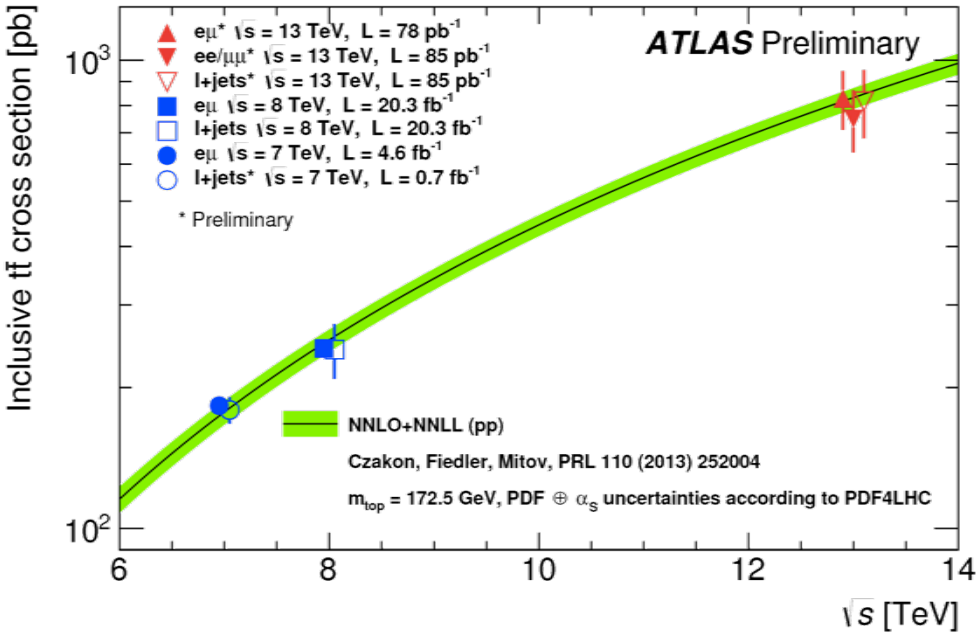


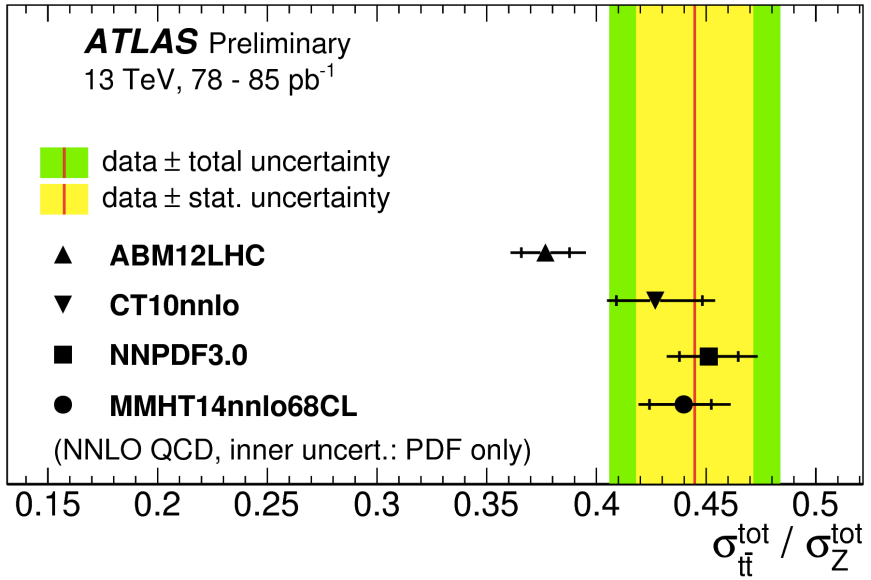


physics at 13 TeV

top pair production

ATLAS-CONF-2015-033
ATLAS-CONF-2015-049





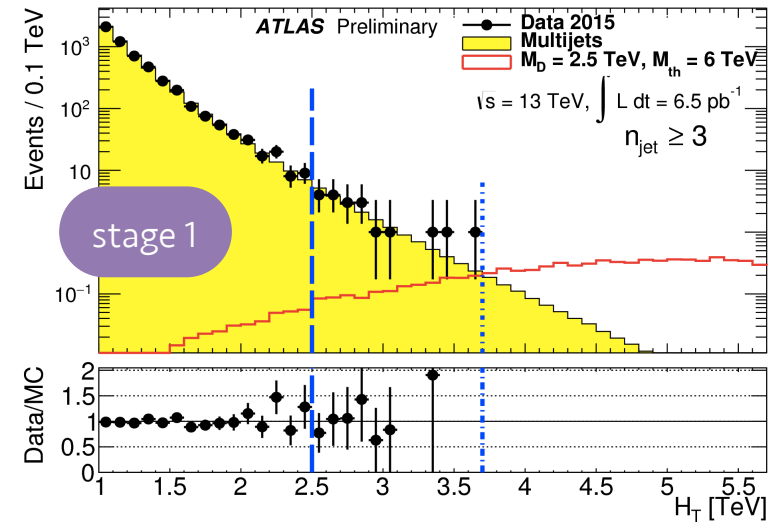
ATLAS-CONF-2015-043

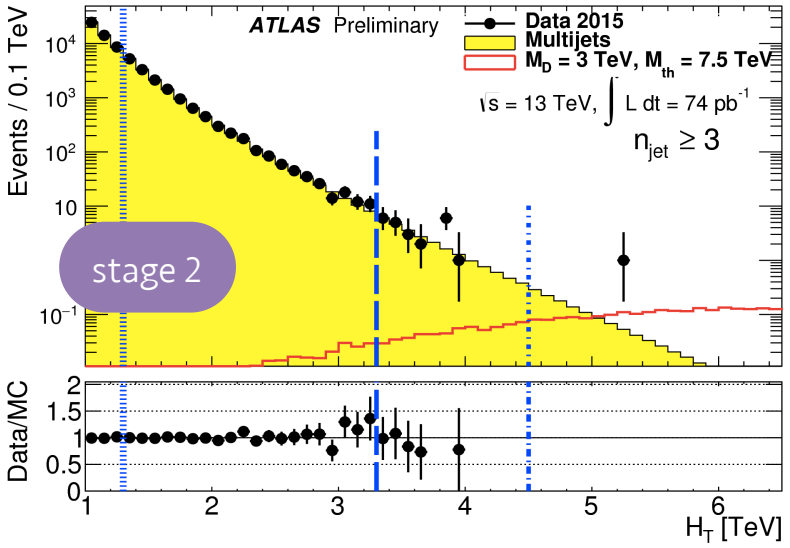
physics at 13 TeV

black holes search with 3+ jets

Low-scale gravity search: simple?

- search for strong gravity states (e.g. quantum black holes)
  - decay spectacularly: many jets (&c.)
    - 0-lepton background is mostly QCD
      - ⇢fit H_T distribution in validation region
  - √s=13 TeV: huge increase in cross sections
    - Will black holes overwhelm data sample?
      - ⇢analyze ~10% of data first, where control region contamination is small





physics at 13 TeV

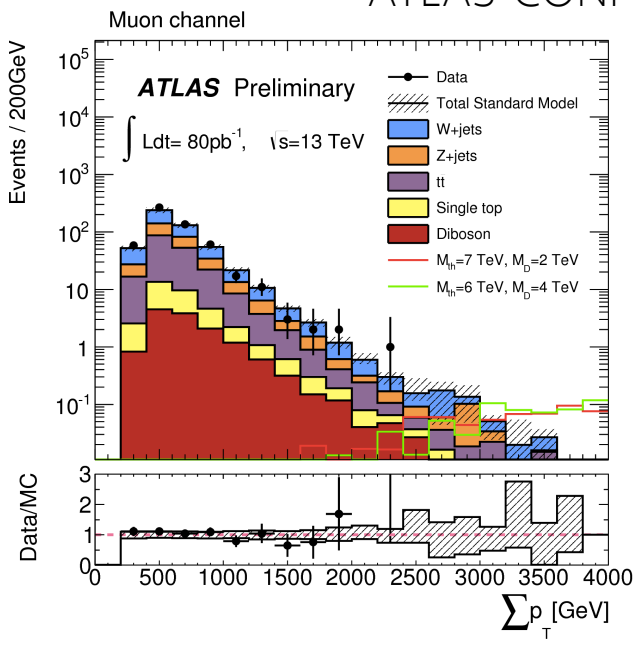
black holes search with lepton + jets

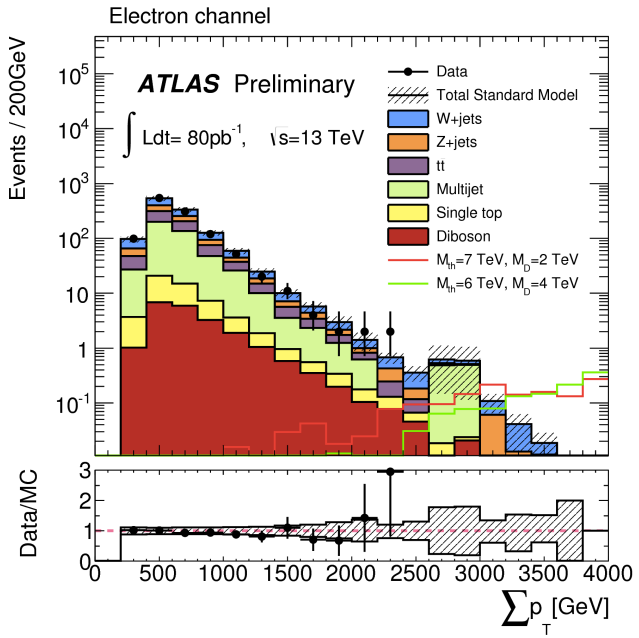
ATLAS-CONF-2015-046

Low-scale gravity search: simple?

- search for strong gravity states (e.g. quantum black holes)
  - decay spectacularly: many jets (&c.)
    - 1-lepton background is mostly W/Z + jets, with small fake electron contribution
  - √s=13 TeV: huge increase in cross sections
    - Will black holes overwhelm data sample?
      - ⇢use MC predictions normalized in W/Z/ttbar control regions

      (corrections range from 0.68-1.19)

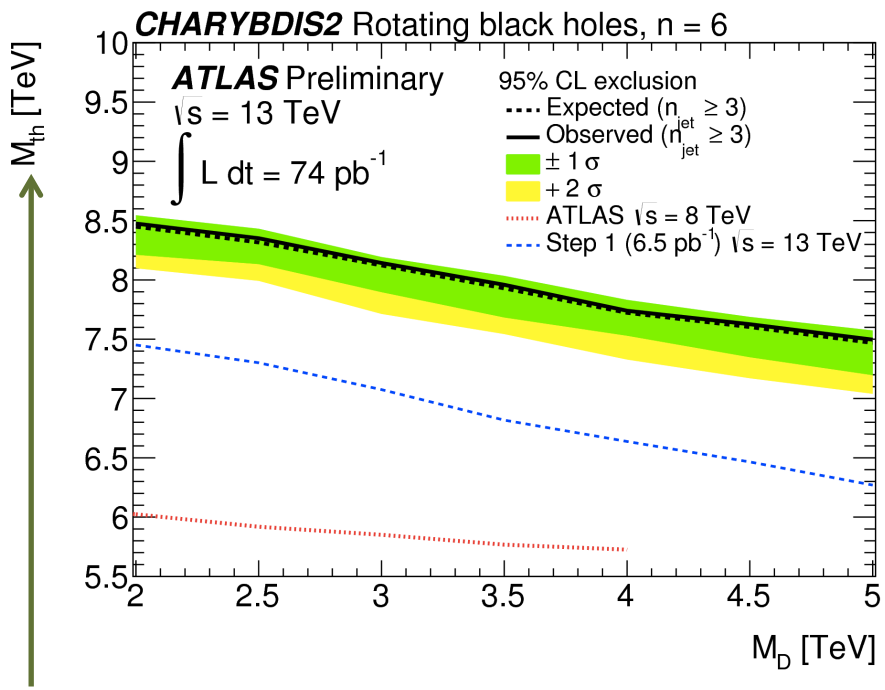


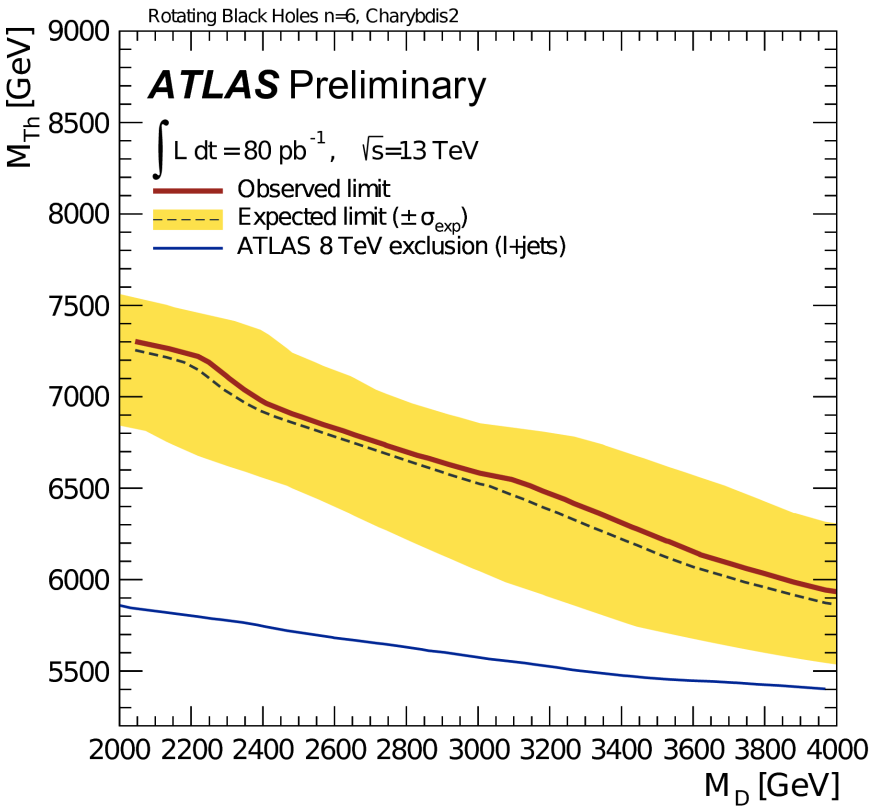


ATLAS-CONF-2015-046

physics at 13 TeV

- limits set with a grid of signal samples (fast simulation) in m_D, $m_{(Th)}$ Charybdis benchmark model

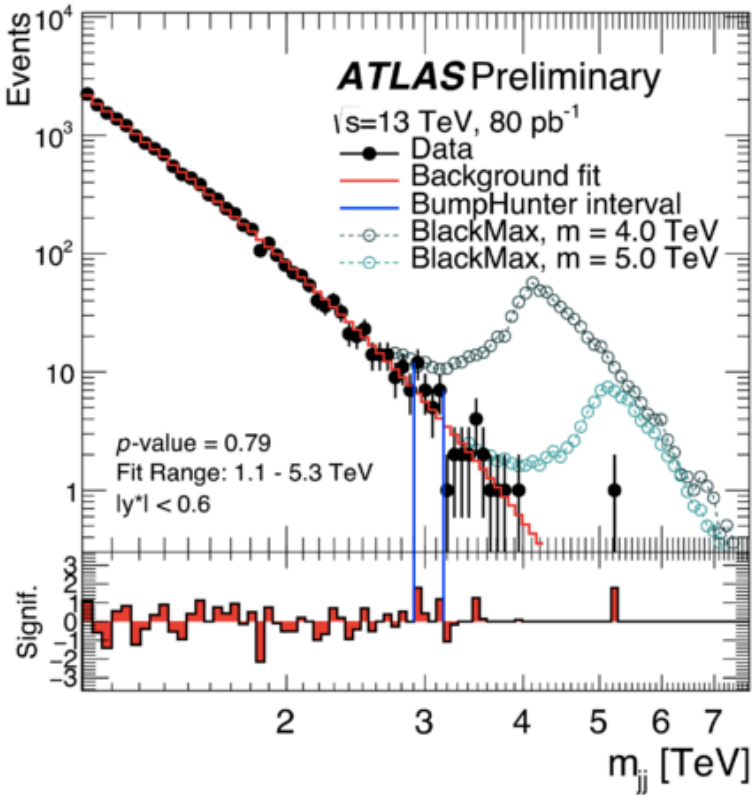


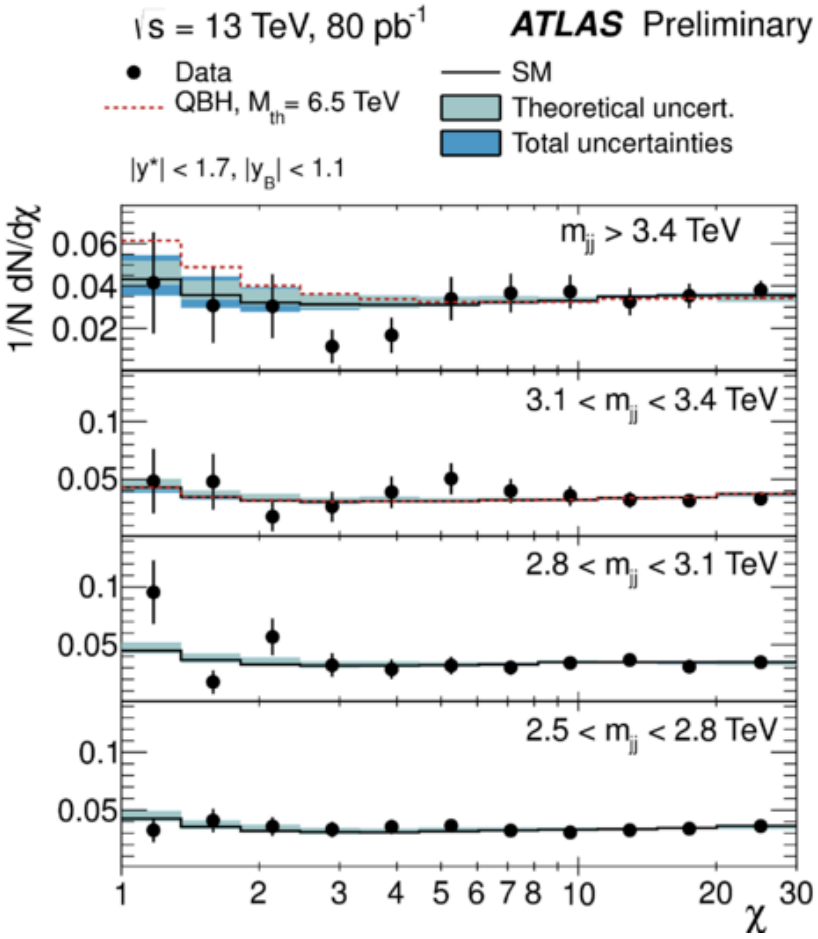


threshold for BH production

physics at 13 TeV

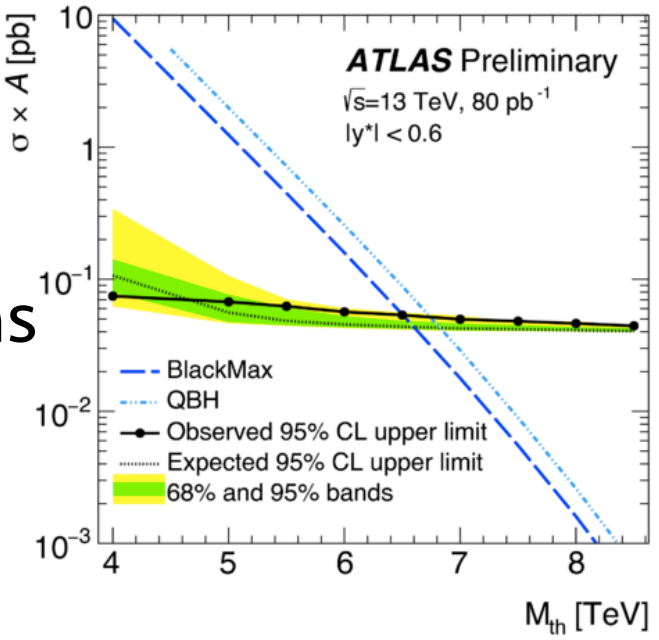
ATLAS-CONF-2015-042

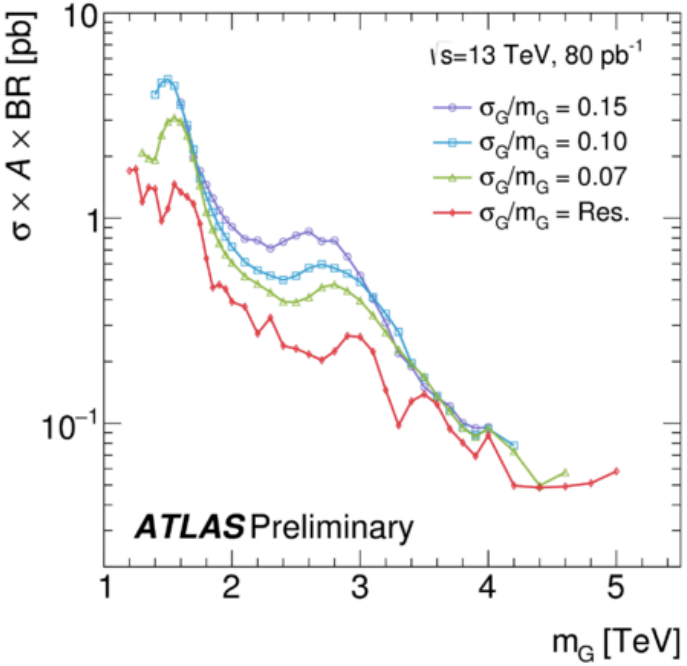


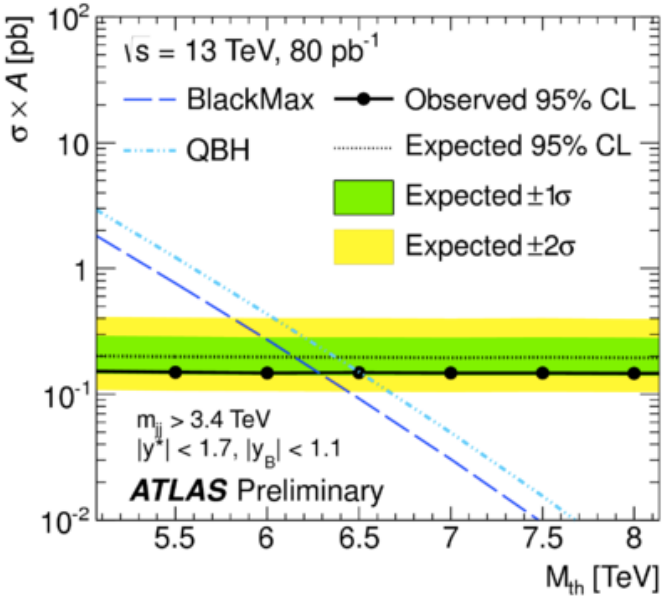


physics at 13 TeV

- BumpHunter limits: dependent on width
- Dijet topology also constrains QBH near threshold

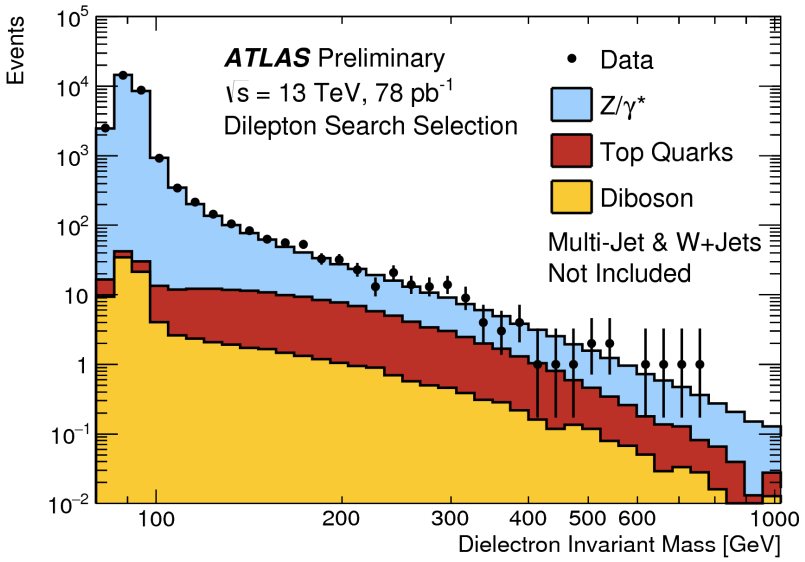




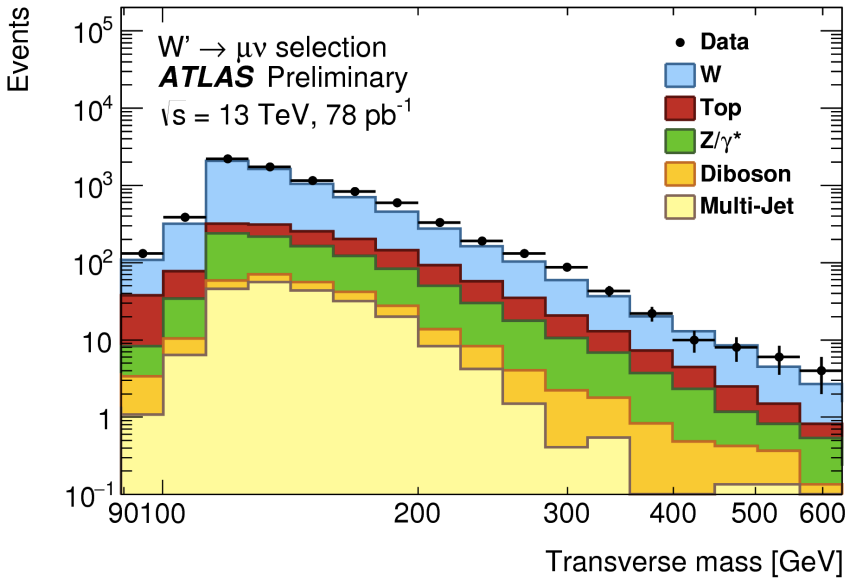


outlook at 13 TeV

Z′



W′



awaiting updates with more integrated luminosity

summary

Things look good at the beginning of Run II:

- Run I confirmed the SM prediction in a wide range of detailed measurements and searches
  - Run 1 impact on modeling at 13 TeV is already visible
  - We have an arsenal of measurement and analysis techniques for elusive signals
- Successful upgrades over the long shutdown
  - Reflected in a strong suite of early SM and search results
- This year's data may not answer all the questions raised in Run 1 -- but long-term prospects look bright!